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DSA REPORT NO. 335

# A PROTOTYPE INTERFACE TO ADAPT DECISION AIDS TO USER SCENARIO ASSUMPTIONS

FINAL REPORT



prepared under contract no. N00014-80-C-0322 for:

Office of Naval Research
Department of the Navy
800 North Quincy Street
Arlington, Virginia 22217

Attn: Dr. Neal D. Glassman



July 1981

DECISION-SCIENCE APPLICATIONS, INC.
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The Emissions Control Decision Aid (EWAR) which is discussed in this report demonstrates how a decision aid can help a battle group commander evaluate the quality of proposed emissions control postures. The aid contains displays that convey the quality of air surveillance provided by a set of emitting task group radars, displays that convey the useful targeting information provided to an adversary by this set of

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emitting radars, and displays concerned with the overall mission effectiveness as a result of both surveillance quality and ship identity information conveyed.

This work focused primarily on the development of a new kind of aid user interface, on methods for aid developers to acquire information needed to develop such an interface, and on adding a new aid capability recently identified as especially important.

The new user interface clarifies the structure of the aid, communicates its capabilities and limitations to users, suggests how this aid could interface with other shipboard systems, and increases the range of scenarios to which the aid is applicable. The interface specifies the aid data requirements and helps the user calculate the aid-required parameters from more fundamental tactical or engineering data. The interface provides automatic sensitivity tests which compute the sensitivity of the decision itself to data or scenario assumptions and help identify the most important uncertainties influencing the choice of an emissions control alternative.

DSA obtained the operational information needed for design of the interface by conducting in-depth interviews with Naval officers involved with emissions control planning. To structure these interviews, DSA worked with SRI International to develop an interviewing methodology using influence diagrams (a method adapted from management consulting). The resulting interview methods described in this report provided a highly efficient and effective method for obtaining the information needed to design an operational user interface. In addition, the interviewing methods assured that the resulting interface design would be structured in a way natural to the Naval officers.

An important new technical capability developed for the aid allows the user to explore the way that adversary deductions about ship identity can vary depending on the degree to which he anticipates deceptive tactics. The expectation of deceptive tactics can be reflected in the aid by adjusting the assumed a priori probability that a high valued unit will have many emitters turned on. Although it is difficult for a planner to estimate the extent to which an adversary actually anticipates a deceptive emissions posture, the availability of different deductive approaches should allow the user to develop a more realistic understanding of the possible variability of adversary deductions. In addition, an ability to examine consequences of alternative adversary deductive methods also opens the possibility of a game-theory-like min/max solution which could be used to hedge against the possibility that the adversary may anticipate a deceptive emissions control posture.

## ACKNOWLEDGMENT

DSA would like to thank the following Naval officers who consented to be interviewed for this project and Mr. Robert Lawson of the Office of Naval Research who arranged most of the interviews:

Vice Admiral David Richardson (Ret.)

Commander Steve Schrobo

Lt. Commander Dan Sigler

Lt. Commander John Burger

Commander John Vanderslice

Commander James Julian

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EXECUTIVE SUMMARY

The Emissions Control Decision Aid (EWAR) which is discussed in this report demonstrates how a decision aid can help a battle group commander evaluate the quality of proposed emissions control postures. The aid contains displays that convey the quality of air surveillance provided by a set of emitting task group radars, displays that convey the useful targeting information provided to an adversary by this set of emitting radars, and displays concerned with the overall mission effectiveness as a result of both surveillance quality and ship identity information conveyed.

EWAR has several important characteristics that were most frequently mentioned by Naval officers impressed with its long-term potential. First, the aid addresses an important tactical problem not presently addressed by other automated aids. Second, the aid has a unique ability to quantify the useful information conveyed to an adversary by the pattern of task group emissions. Third, the aid can express plan quality in terms of a meaningful measure of effectiveness.

The emissions control decision aid is one of a number of demonstration decision aids that were developed under ONR's Operational Decision Aids programs. The purpose of the ODA program was to demonstrate how existing methodologies in decision theory, display technology, operations research, and computer technology could be applied to provide new forms of decision aids for the operational Navy. The development of decision aids within the ODA program was stretched out over several years to provide time for the analysis and evaluation of lessons learned at each stage of the development process.

This document, which is the final report on the EWAR decision aid under the ODA program, is concerned primarily with the final development stages of the EWAR aid. Like the ODA program itself, the work documented here was concerned both with increasing the suitability of a demonstration aid for eventual operational use, and also with developing procedures generally applicable to other types of decision aids.

This work focused primarily on the development of a new kind of aid user interface, on methods for aid developers to acquire information needed to develop such an interface, and on adding a new aid capability recently identified as especially important.

The new user interface clarifies the structure of the aid, communicates its capabilities and limitations to users, suggests how this aid could interface with other shipboard systems, and increases the range of scenarios to which the aid is applicable. The interface specifies the aid data requirements and helps the user calculate the aid-required parameters from more fundamental tactical or engineering data. The interface provides automatic sensitivity tests which compute the sensitivity of the *decision* itself to data or scenario assumptions and help identify the most important uncertainties influencing the choice of an emissions control alternative.

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## 1.0 INTRODUCTION

Since 1976 Decision-Science Applications, Inc., (DSA) has been developing a demonstration Emissions Control Decision Aid as part of the Office of Naval Research Operational Decision Aiding program. Throughout this period DSA focused on advancing decision aiding technology in general, on demonstrating the value of decision aiding in the tactical command environment, and on developing a specific illustrative aid suitable for fleet adoption. DSA believes that considerable progress has been made toward each of these objectives. DSA's illustrative Emissions Control Decision Aid (EWAR) not only performed very well during formal psychological testing, but it has generated substantial interest within the operational Navy. During the past year DSA has continued to increase the suitability of the aid for a more realistic operational evaluation and, in addition, has developed an aid design methodology potentially useful to other decision aid developers. This final report details the status of the Emissions Control Decision Aid at the time that the Operational Decision Aiding program ended, emphasizing in particular work performed subsequent to the last interim report. This report does not, however, repeat information available in earlier publications.[1]

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[1] G. E. Pugh et al., Development and Evaluation of an Emissions Control Decision Aid, Decision-Science Applications, Inc., Report No. 246, July 1980.

D. F. Noble et al., Manual for Test Subjects Using the Electronic Warfare (EWAR) Decision Aid, Decision-Science Applications, Inc., Report No. 126, March 1979.

G. E. Pugh et al., An Emissions Control Decision Aid, Decision-Science Applications, Inc., Report No. 66, July 1978.

G. E. Pugh et al., An Electronic Warfare Decision Aiding System for Fleet Air Defense (An R & D Status Report), General Research Corporation, February 1977.

The Emissions Control Decision Aid demonstrates how a decision aid can help a battle group commander evaluate the quality of proposed emissions control postures. The aid contains displays that convey the quality of air surveillance provided by a set of emitting task group radars, displays that convey the useful targeting information provided to an adversary by this set of emitting radars, and displays concerned with the overall mission effectiveness as a result of both surveillance quality and ship identity information given away. The most complete description of the aid displays and their use to evaluate emissions control plans is available in the aid user's manual.[1]

## 1.1 STATUS OF AID PRIOR TO CURRENT EFFORT

The development of a decision aid from its initial conceptualization to its final installation for operational use may pass through several distinct stages. The first stage is the identification of tactical operations which could benefit from an automated aid, and the identification of the kind of information that an aid should provide to best support these operations. Once the function of the aid is understood, the next stage is development of appropriate mathematical tools to provide the desired information and the design of effective displays. In the following stage, the preliminary aid so designed is screened in a formal aid evaluation for operational feasibility, preferably by a disinterested evaluator. If the aid shows promise in this preliminary screening, then it may be modified as suggested by the evaluation and evaluated again in a less structured but more operational-like setting like a laboratory wargame. If in this setting the aid seems to confer significant operational advantages, then a prototype might be developed for evaluation in a war exercise.

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[1] D. F. Noble et al., Manual for Test Subjects Using the Electronic Warfare (EWAR) Decision Aid, Decision-Science Applications, Inc., Report No. 126, March 1979.

By mid-1979 DSA had prepared a version of the Emissions Control Decision Aid suitable for formal evaluation. During this evaluation most of the Naval officer test participants thought that the aid performed an important planning function well. These subjective opinions were consistent with the statistical evaluation of participant performance, which indicated that the aid significantly improved the quality of selected emissions control plans.

Three aspects of the aid were most frequently mentioned by Naval officers impressed with its long-term potential. First, the aid addresses an important tactical problem not presently addressed by other automated aids. Second, the aid has a unique ability to quantify the useful information conveyed to an adversary by the pattern of task group emissions. Third, the aid can express plan quality in terms of a meaningful measure of effectiveness.

The aid's subject, emissions control, is important both in itself and because it is part of the larger information warfare problem. In information warfare, each of the combatants attempts to achieve an information advantage over its adversary by learning as much as possible about adversary combat resources and intentions while simultaneously denying to an opponent such information about itself. Since such information can be critical to the success of a military mission, the quality of information warfare tactics is very important. Despite the importance of information warfare, inherent technical difficulties have impeded the development of effective information warfare decision aids. Because the Emissions Control Decision Aid suggests solutions to many of these difficulties, it could significantly improve information warfare decisions.

Perhaps the most useful information needed by a commander exploring information warfare alternatives is the adversary's current estimate of the task group. Knowing what the enemy knows permits one to design effective cover and deception tactics and to avoid unnecessary operational constraints designed to deny information currently possessed by the adversary. The decision aid's ability to estimate the inferences that could be drawn from the pattern of task group emissions permits the staff to estimate what the adversary could already have learned. Therefore, the "information given away" module in the aid is a key to improving information warfare tactics.

Without an aid it may be very difficult to assess the contribution of an information warfare procedure to overall mission success. Rather, it may be practical only to calculate much more narrow consequences of a procedure. For instance, without an aid it may be determined that turning on a radar will permit detection of particular types of air threats at particular ranges, and that the radar emission can be detected, localized, and classified by certain kinds of adversary surveillance devices. Although useful, such narrow effectiveness measures fall short of what a planner would really like to know. A more meaningful effectiveness measure, for instance, would be the extent to which the radar emission permits an adversary to target the high value unit, and (given adversary and friendly defense capabilities) the implications of such targeting ability to high value unit survivability. The ability of the aid to express the consequences of emissions control postures in terms of mission effectiveness links tactical decisions to task group mission goals.

Because these capabilities were potentially very useful to the NAVELEX sponsored Counter Surveillance Assessment Program (CSAP), last year DSA was asked to adapt them to the needs of this program. In particular, DSA was assigned to provide that program with needed decision aid support, to help it express outcomes using meaningful measures of effectiveness, and to help it estimate the useful information conveyed by a task group's emissions.

Despite such past successes and promise, the aid at the start of the current year's work had several limitations. It could evaluate only a relatively narrow class of scenarios. It also contained many assumptions implicit in the model's parameter values and equation structures which if not understood by a planner could lead to aid misuse. Finally, no effort had yet been made to insure that the aid would integrate smoothly with other shipboard systems and with the ship staff organization.

At the time of the formal aid evaluation, these limitations did not seriously detract from the aid's ability to demonstrate important decision aiding capabilities. The aid's design strengths--its subject, its ability to model adversary intelligence inferences, and its linkage of emissions control posture to mission success--were obvious even in the limited formal test environment. The limitations of the demonstration system were not stressed in the controlled test environment. DSA selected scenarios appropriate to the aid for the test. Further, DSA selected parameter values appropriate for the chosen scenarios. Since the evaluation considered the aid only in a stand-alone mode, its ability to interface with other shipboard systems was not evaluated.

Despite their irrelevance to the formal test environment, such limitations could seriously undermine the aid's operational usefulness. Therefore, DSA proposed for the current effort a research and development program designed to remedy these difficulties. This program was designed both to increase the suitability of the aid for fleet use, and also to develop new aid design techniques that could be of general interest to the decision aiding community.

## 1.2 SUMMARY OF WORK COMPLETED DURING THE CURRENT CONTRACT PERIOD

At the start of the current contract period the aid needed to be improved in three important respects. First, a planner needed to be protected from aid misuse due to subtle assumptions implicit in the model. Second, the classes of scenarios that the aid could address needed to be broadened. Finally, the capability to interface the aid with other shipboard systems needed to be enhanced.

It seemed likely that each of these objectives could be addressed through the development of an advanced user interface which could communicate aid assumptions to the user in operational terms. Such an interface would permit the user to better understand aid functions and to provide the aid with input parameter values and scenario assumptions appropriate for specific planning needs. If the aid were unable to accommodate the assumptions required for any specific scenario, the interface could so advise the user. If the use of the aid in a particular scenario seemed to be marginally appropriate, such an interface could help the user decide whether he could profitably use the aid. By clarifying the aid capabilities and data input requirements, the interface would also clarify which other shipboard systems could provide inputs to the aid, and which could accept the aid outputs.

The development of such an interface requires that the aid be compatible with all of the major scenario types likely to be considered by an emissions control planner, including scenarios unrelated to those appropriate to the aid. It seems probable that the technical developers of any aid are likely to be unaware of many important aid-related scenarios because of their lack of familiarity with Navy operational procedures. To minimize the chance that the aid interface would be seriously incomplete or organized in a manner that would seem awkward to Navy planners, emissions control scenarios and procedures were discussed in depth with Naval officers involved with emissions control. These interviews focused both on the possible uses of emissions control and on the different factors that should be included when evaluating alternative emissions control postures.

DSA felt that a considerable amount of interviewing might be required to obtain this information and that officers with the necessary background would be extremely busy and difficult to reach. Therefore, it was important that all interviews be as efficient as possible. The needed information must be obtained on the first try; the format of the information elicited from different interviewed officers must facilitate combining and comparing results from different interviews, and after the interviews the Naval officers should feel that their time had been well spent. DSA felt that a decision structuring aid being developed by the Decision Analysis Group at SRI International might provide a mechanism that could be used to obtain the needed interviewing efficiency, and therefore arranged for their assistance on a subcontract basis for the interviewing portion of this project.

In cooperation with SRI, a specific interviewing methodology was developed which exploited influence diagrams to organize and structure communication within the interviews. The interview procedures employed proved effective and potentially useful for improving communication between aid developers and users during aid development. Because the technical developers of decision aids are typically mathematicians, physicists, and computer scientists who may not be personally familiar with all aspects of the decision problem, there is a high probability that certain issues that are important to the ultimate user will be overlooked during initial design consultations. Such omissions can result in aids that do not work to the user's satisfaction. Since this communication difficulty between aid designer and aid user is often encountered during the development of decision aids, the systematic interviewing approach which was developed and used during this work should be helpful to other decision aid developers. Appendix A of this report discusses the interview procedures and summarizes the information acquired during these interviews. It describes the preliminary planning required to structure the interview, the interviewing process employed, and the structuring of the interview results to provide a coherent view of information warfare.

After completing the interviews, DSA began to design the user interface. Like the interviewing phase, which furthered both the specific emissions control aid as well as decision aiding technology in general, the interface design which is reported here is intended to improve the aid while contributing to general decision aiding technologies. The interface developed includes features designed to clarify the aid structure, to help with parameter estimation, and to facilitate aid sensitivity analysis. Section 2.0 describes the application of the interview results to the interface design and describes the new interface in detail.

During the interviews, DSA became aware that the aid's modeling of adversary ship identity inference processes was far too narrow. Therefore, DSA altered the aid software to permit examination of alternative adversary inferences, including inference methods which take into account the possibility of purposely deceptive emissions control postures. Section 3.0 describes these more sophisticated information warfare tactics.

The material described in each of the following sections and the appendix describes potentially important research products. The appendix, which outlines the use of influence diagrams to structure the interview, provides a method that can significantly improve communication between aid developers and intended aid users. Although influence diagrams have been previously used to structure management consulting discussions, their application to decision aid development may be new. Their use for interface design is particularly appropriate because the interview material (which emerges from the interview organized in a way natural to users) can be easily adapted in this way to an interface structure which is also organized in a way that is natural to users.

The resulting EWAR interface is distinguished by a new set of interface diagrams, aids for setting input parameters, and automated sensitivity tests. The interface diagrams illustrate the aid structure and clarify the relationships between required aid inputs and other shipboard systems. In addition, it shows the relationships between input data, scenario assumptions, and output displays. The interface specifies the aid data requirements and helps the aid user calculate aid-required parameters from more fundamental tactical or engineering data. The sensitivity tests compute the sensitivity of the decision itself to data or scenario assumptions and help identify the most important uncertainties influencing the choice of an emissions control alternative.

Calculating adversary inferences about U.S. ship disposition has in the past required explicit assumptions about the adversary's a priori probabilities for alternative U.S. information warfare tactics. The ability to compute alternative adversary inferences for different a priori assumptions, and the evaluation of game theory inferences from a set of such assumptions, may provide a way to reduce the need for a U.S. emissions control planner to make assumptions about an adversary's beliefs of U.S. tactics.

The concurrent DSA participation in the NAVELEX Counter Surveillance Assessment Program was very helpful to DSA in the efforts described in this report. That work increased our understanding of Navy doctrine and requirements in the broader information warfare context. Most important, perhaps, the technology DSA developed for CSAP can be easily used in the emissions control aid, greatly increasing its generality. The combination of work sponsored by the Operational Decision Aiding program and the Counter Surveillance Assessment Program has moved the aid far beyond the demonstration version available at the start of the current effort to a point where it could become a tool that would significantly improve planning for emissions control and for information warfare.

## 2.0 NEW INTERFACE FOR EMISSIONS CONTROL DECISION AID

Emissions control plans are implemented to support specified task group mission objectives. These plans, as one component of task group operations, must reflect command objectives, must satisfy numerous operational constraints, and must accurately reflect the existing tactical environment. An emissions control aid, therefore, should enable the planner to evaluate how well alternative plans contribute to mission objectives and how they impact other operations. Furthermore, its calculations should reflect those environmental and operational factors most critical for each desired aid application.

The new aid interface helps the aid user to realize the full benefits potentially available from the aid. The interface gives him a better understanding of the structure of the aid, its assumptions, and its limitations.

More specifically, the interface anticipates general questions that may be common to users unfamiliar with the aid. There are interface options which help answer the following questions:

1. How do I (the user) know that the aid considers all factors that I think are important?
2. Although I am assured that the aid considers these factors, how do I know that they are modeled appropriately for my needs?
3. I am not sure what value to assign to a planning factor. Should I go to much trouble to find the appropriate value?
4. What value does the aid currently assign to planning factors?

5. I do not understand the diagrams in this interface. What do these diagrams mean?

6. I believe accurate values for planning factors are required. How can I estimate these values?

This section will describe the aid interface in detail. It will illustrate and explain all interface influence diagrams, will describe the input command structure, and will indicate how the interface can answer each of these questions. It will give examples of specific interface functions. Finally, it will discuss how the interface relates aid functions to other Navy systems.

## 2.1 REVIEW OF ASSUMPTIONS IMPLICIT IN EMISSIONS CONTROL AID

A principal design goal of the interface is to efficiently communicate the functional limitations imposed by the aid's internal structure, its mathematical representation of physical processes, and its parameter settings. This section reviews the most important limitations of the aid at the start of the current effort.

The emissions control decision aid contains four computational modules: a radar module concerned with threat detection; an air defense module for calculating the quality of task group air defense given a surprise attack; a strike tactics module for calculating adversary air strikes; and a ship identification module for calculating the information given away by a pattern of radar emissions. Each of these modules contains equations and algorithms that imply specific operational procedures and capabilities. The following subsections sketch these equations and outline the implied assumptions.

Few of these assumptions are fundamental to the aid. Most occur because they seemed most appropriate to the more narrow scenarios analyzed by the demonstration version of the aid. Using the new techniques developed for CSAP and replacing some

DSA-developed modules with similar ones developed for other Navy programs would considerably shorten these lists of inherent aid assumptions.

### 2.1.1 Assumptions in Radar Module

The radar equations used by the aid are detailed in the report of July 1978, DSA Report No. 66, An Emissions Control Decision Aid. These equations calculate the radar detection rates and cumulative detection probabilities provided by tactical sea-based and air-based radars under various weather and electronic jamming conditions. Some of the assumptions implied by these equations are:

1. There are no detections of adversary missiles by passive task group monitoring systems. All detections are by task group active radars. (Adversary is in an EMCON condition).

2. The altitude of the threat affects only the range at which it can first be detected. Within this range the altitude does not affect detectability.

3. The threat altitude is constant along its attack trajectory. All threats are launched from platforms beyond the range of tactical surveillance radars.

4. Sea search radars do not contribute to task group air threat detection capability.

5. Special capabilities of three-dimensional radars are not considered.

6. Radars do not interfere with each other.

### 2.1.2 The Air Defense Module

The aid has a highly aggregated area and point defense model. The area defense assumes a fixed latency time between first detection and earliest engagement opportunity. Thereafter it assumes a uniform probability of kill per unit time until the threat reaches a launch radius and zero probability of kill by the area defense after the threat reaches the launch distance. A point defense can destroy weapons that reach the launch distance. Some of the assumptions implicit in the air defense model are:

1. The air defense interception probability is independent of attack size. There are no saturation effects.
2. Communications between ships and early warning aircraft are perfect.
3. Time for aircraft to intercept threat is independent of threat bearing.
4. Detection of first threat does not change detection probabilities for others.
5. All detected threats are tracked perfectly.
6. Bearing of weapon with respect to ship orientation does not impact damage probability.
7. Weapon terminal homing is independent of ship EMCON state.
8. Probability of kill and probability of hit jointly determine expected damage per hit. Each hit kills a constant fraction of surviving ship value.

### 2.1.3 Assumptions in Strike Tactics Module

The adversary missile attack is defined by the numbers and types of missiles directed against the ship, by their altitude, velocity, and bearing and by the allocation of specific weapons to different ships. The aid user may specify each of these factors explicitly, or he may choose instead to specify one of four general allocation rules, letting the aid compute the details. The strike allocations are described in DSA Report No. 66, An Emissions Control Decision Aid. Some of the assumptions are:

1. All threats are directed radially toward the ship from a platform beyond the range of task group tactical surveillance sensors.

2. Threat penetration capability depends on velocity, altitude, and radar cross section. Increased capabilities from electronic countermeasures must be input through these parameters.

3. In cases where an adversary must infer ship identity, the adversary infers target identity using Bayesian logic.

4. Adversary weapon allocation is based on target identity inferences.

### 2.1.4 Assumptions Implicit in Ship Identification Module

The algorithm used by the aid to calculate information conveyed by a pattern of task group radar emissions is an approximation to Bayesian inference. In its normal operation, the Bayesian calculation assumes that all ship formations consistent with the observed pattern of radar emissions are equally probable. Ship assignments that conflict with the observed radar order of battle are much less probable. The aid contains an "other prior information" input which would permit an experienced user to change the allocation rules to reflect other operational factors. In practice, this input is too abstract to be of practical value.

The assumptions in this module were extremely restrictive, and could not be easily relaxed by minor changes to the inference algorithm. However, since a new algorithm developed for CSAP does not require any of these assumptions and can be easily substituted for the current algorithm, it is practical to improve the aid significantly by replacing the Bayesian algorithm with the new one. These assumptions were:

1. The adversary knows the composition of the task group.

2. The adversary has localized all platforms, but must infer the identity of the platform at each location from the pattern of task group emissions.

3. The adversary knows the radar order of battle information for the task group.

4. The adversary will detect and localize all task group air and sea search radar emissions.

5. The adversary classifies each detected radar emission, by type of radar, but is unable to classify emission by ship of origin.

6. The adversary will not use information conveyed by electromagnetic radiation other than air and sea search radars, nor by nonelectromagnetic signals such as acoustic or infrared radiations.

## 2.2 DESCRIPTION OF INTERFACE INFLUENCE DIAGRAMS

The interface consists of a hierarchical set of diagrams, a set of commands for exercising interface options, and displays showing the results of these interface commands. The hierarchical diagrams show the relationships between emissions control planning factors, emissions control alternatives, and mission objectives. The commands permit the aid user to ask the kinds of questions listed above. The interface output displays provide the answers to these questions.

### 2.2.1 Main Level Interface Diagrams

Figure 2-1, the main level interface diagram, shows the overall architecture of the aid. This interface diagram focuses on one particular mission, emissions control for task group defense. Although this is the only information warfare scenario for which the aid presently links emission control posture to an overall mission effectiveness, it is not the only scenario for which the aid would be useful. The information provided by the

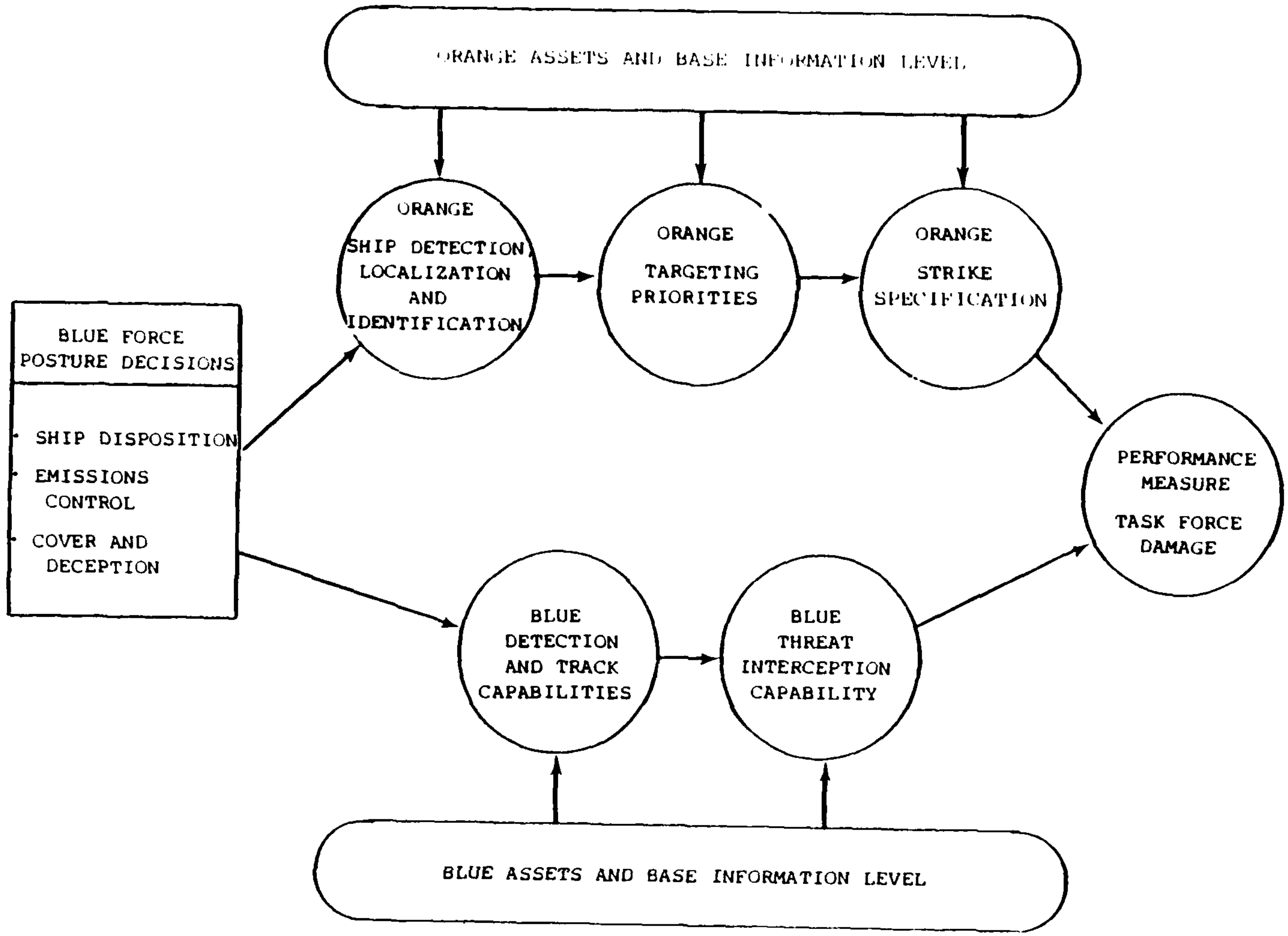



Figure 2-1. Main Level Interface Diagram for Emissions Control Decision Aid. Each circle corresponds to an aid output display. Rounded rectangles represent the aid data base. The rectangle indicates decision alternatives.

aid concerning Orange ship identification capabilities and Blue surveillance effectiveness could help with emissions control planning in many different circumstances.

Each of the elements in the main interface level corresponds to an aid output display which is either the same or generalized from a display described in the user's manual prepared for the formal aid evaluations. Each of these elements may be expanded to a more detailed influence diagram that includes planning factors identified in the interviews as being important to emissions control in information warfare.

The box on the far left, labeled "Blue Force Posture Decisions," concerns decision alternatives such as task group disposition, emissions control posture, and selected cover and deception tactics like the use of blip enhancers or deceptive van that mimic radars. Output displays, Figs. 2-2 and 2-3, associated with this box include maps showing the locations of friendly ships, and summary displays of emissions control posture.

The upper arrow from this box points to "Orange Ship Detection, Localization, and Identification," one of two main influences of emissions control on task group mission effectiveness. "Orange Ship Detection, Localization, and Identification" summarizes the information given away by task group emissions. Its output is an estimate of the adversary's ability to detect, localize, and identify friendly platforms as a consequence of the pattern of task group emissions and other information thought by the aid user to be available to the adversary. Figure 2-4 is the output display which is generalized from that produced by the current aid for this function to include a probability estimate of platform detection and degree of platform localization. This display assumes that the adversary has well localized radar returns from each task group

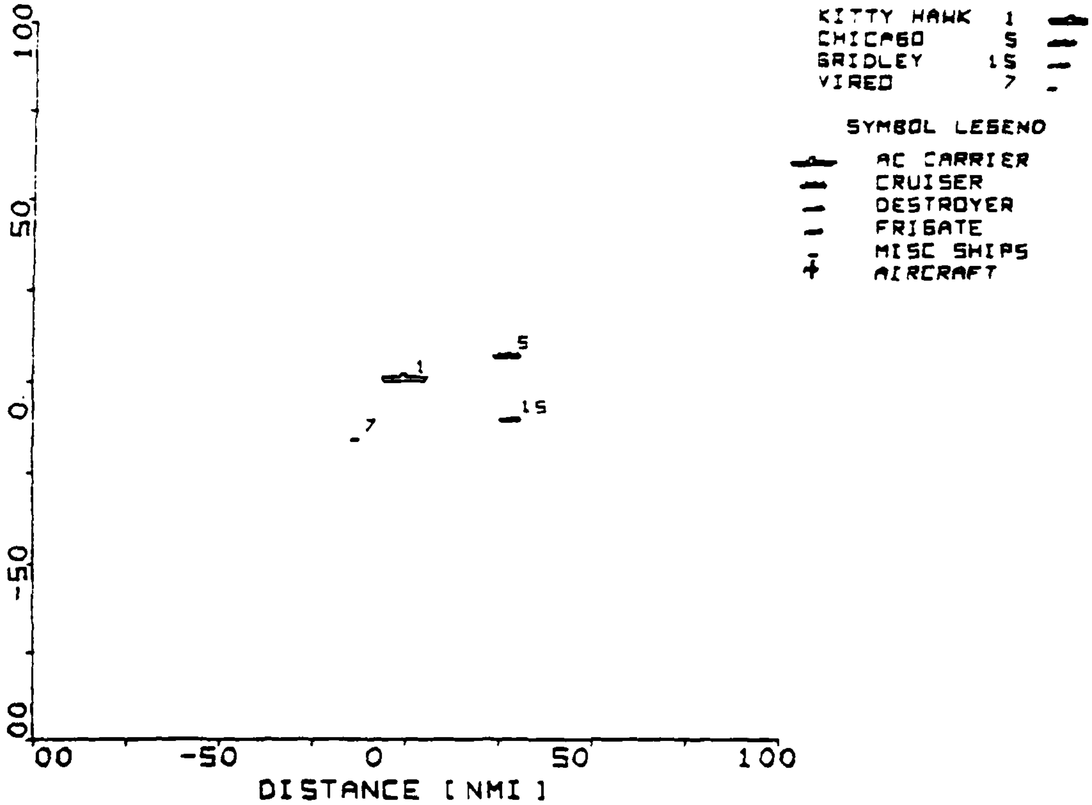



Figure 2-2. Task Force Disposition

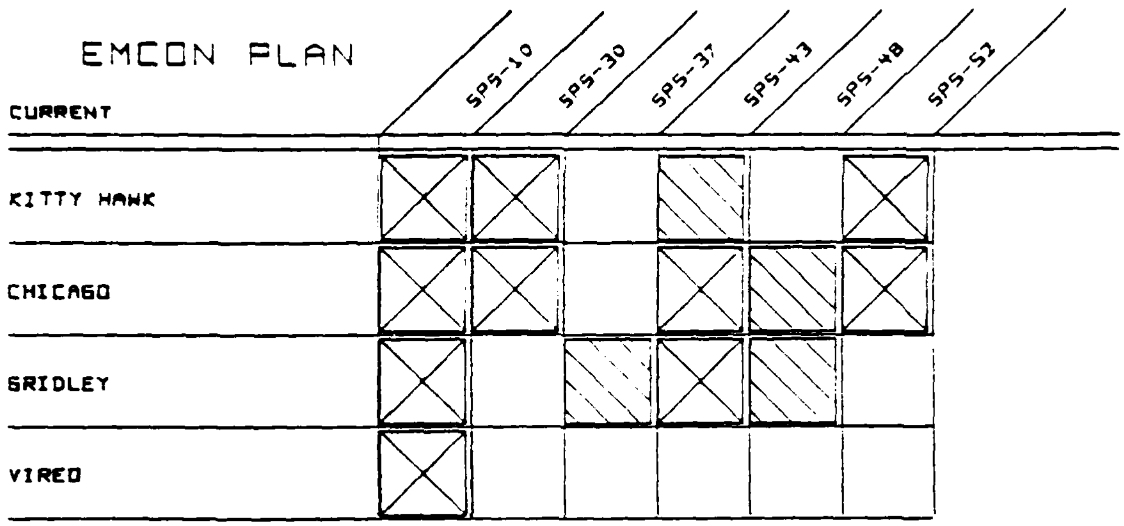



Figure 2-3. Search Radar Order of Battle and Activity. A diagonally hatched square indicates that the ship has the indicated radar, but this radar is not emitting. The cross-hatched square indicates that the radar is emitting. A blank square indicates that the ship does not have the indicated radar.

EMCON PLAN = INFO

| PLATFORM | PROBABILITY OF DETECTION | LOCALIZATION | CLASSIFICATION INFERENCES | |
|---|---|---|---|---|
| | | | SHIP | PROBABILITY |
| KITTY HAWK | .99 | .01 nmi | KITTY HAWK | .125 |
| | | | CHICAGO | .125 |
| | | | GRIDLEY | .25 |
| | | | VIREO | .5 |
| CHICAGO | .99 | .01 nmi | CHICAGO | .5 |
| | | | KITTY HAWK | .5 |
| GRIDLEY | .99 | .01 nmi | GRIDLEY | .5 |
| | | | KITTY HAWK | .25 |
| | | | CHICAGO | .25 |
| VIREO | .99 | .01 nmi | VIREO | .5 |
| | | | KITTY HAWK | .125 |
| | | | CHICAGO | .125 |
| | | | GRIDLEY | .25 |

Figure 2-4. Orange Inference: Ship Detection, Localization, and Classification

ship and knows the composition of the task group but does not know the ship identity corresponding to each radar return.

The arrow from the "Orange ship detection" circle points to the circle "targeting priorities," represented by the aid display of Fig. 2-5. This display summarizes the value assigned by an adversary targeter to each ship in the task group. These values depend on how well the targeter can identify the targets, and also on how important he believes each ship is to the Blue mission.

The adversary strike tactic against the task group depends on how well the adversary can identify targets, on the assets available for attack, on estimates of the attack effectiveness, and on overall adversary mission objectives. The display corresponding to "Orange Strike Specification," Fig. 2-6, is a description of the Orange attack plan. It includes a list of missile types and number to be directed against each target, and the missile launch position relative to each target.

The circle to the right of the main level interface diagram, performance measure, is the mission measure of effectiveness. For the demonstration aid, the measure of effectiveness is task force damage. Figure 2-7 shows the expected damage to the task group given the adversary strike specification as calculated along the upper path in Fig. 2-1 and the quality of the Blue task group defense as calculated along the lower path. By showing how these two paths influence the mission outcome, this diagram conveys how the aid trades off surveillance quality with information given away to compute overall EMCON plan quality with respect to this mission.

Turning now to the lower path, the diagram indicates that the second major consequence of an emissions control plan is its effect on the quality of Blue surveillance. Figure 2-8 is a map

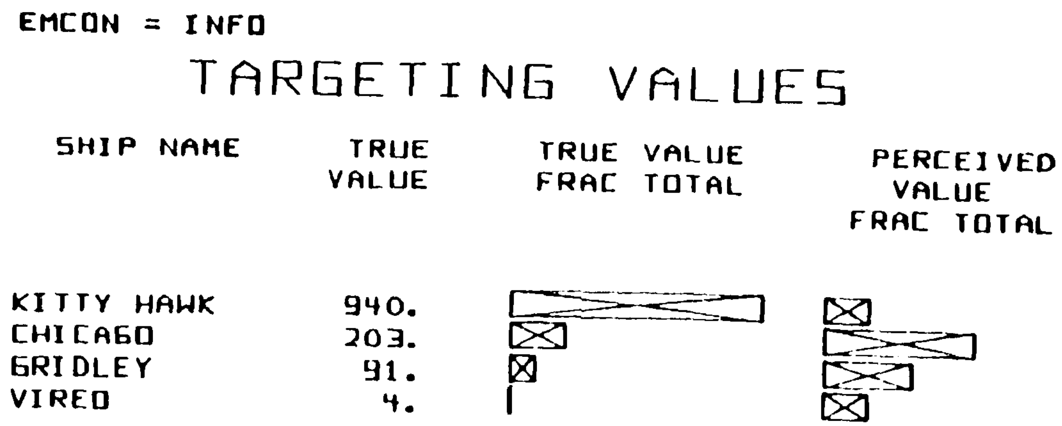



Figure 2-5. Value Assigned by Orange to Each Target Platform. These values depend on the value assigned to each ship (third column) and on how well each ship can be identified (Fig. 3-2).

| THREAT | SHIP | ALLOCATION | RANGE | BEARING |
|---|---|---|---|---|
| DRAGON | KITTY HAWK | 0 | --- | --- |
| | CHICAGO | 8 | 140 | 270° |
| | VIREO | 0 | --- | --- |
| | GRIDLEY | 2 | 275 | 86° |
| TOTALS | | 10 | | |

Figure 2-6. Orange Strike Specification. This strike consists of ten Dragon missiles, a low-flying subsonic cruise missile, directed against the task group. In this case a deceptive emissions control plan succeeds in diverting missiles from the Kitty Hawk to the Chicago and Gridley.

OPTIMAL STRIKE

ATTACKER GUESSES SHIP IDENTITY

FRACTIONAL VALUE REMAINING = 0.872

EMCON PLAN = INFO

| THREAT | SHIP | ALLOCATION | PENETRATION PROBABILITY | # HITS | FRACTION REMAIN | SHIP VALUE INIT | SHIP VALUE REMAIN |
|---|---|---|---|---|---|---|---|
| DRAGON | KITTY HAWK | 0 | --- | -- | ---- | 939.5 | 939.5 |
| | CHICAGO | 8 | 0.534 | 2.7 | 0.28 | 203.5 | 56.5 |
| | VIREO | 0 | --- | -- | ---- | 3.7 | 3.7 |
| | GRIDLEY | 2 | 0.537 | 0.6 | 0.87 | 90.7 | 79.0 |
| TOTALS | | 10 | --- | 3.3 | ---- | 1237.4 | 1078.7 |

Figure 2-7. Emission Control Performance Measure--the Task Force Value Surviving the Adversary Air Strike. This outcome depends on the emission control posture influence on targeting information conveyed by the active radars and also on the quality of air surveillance provided by these radars.

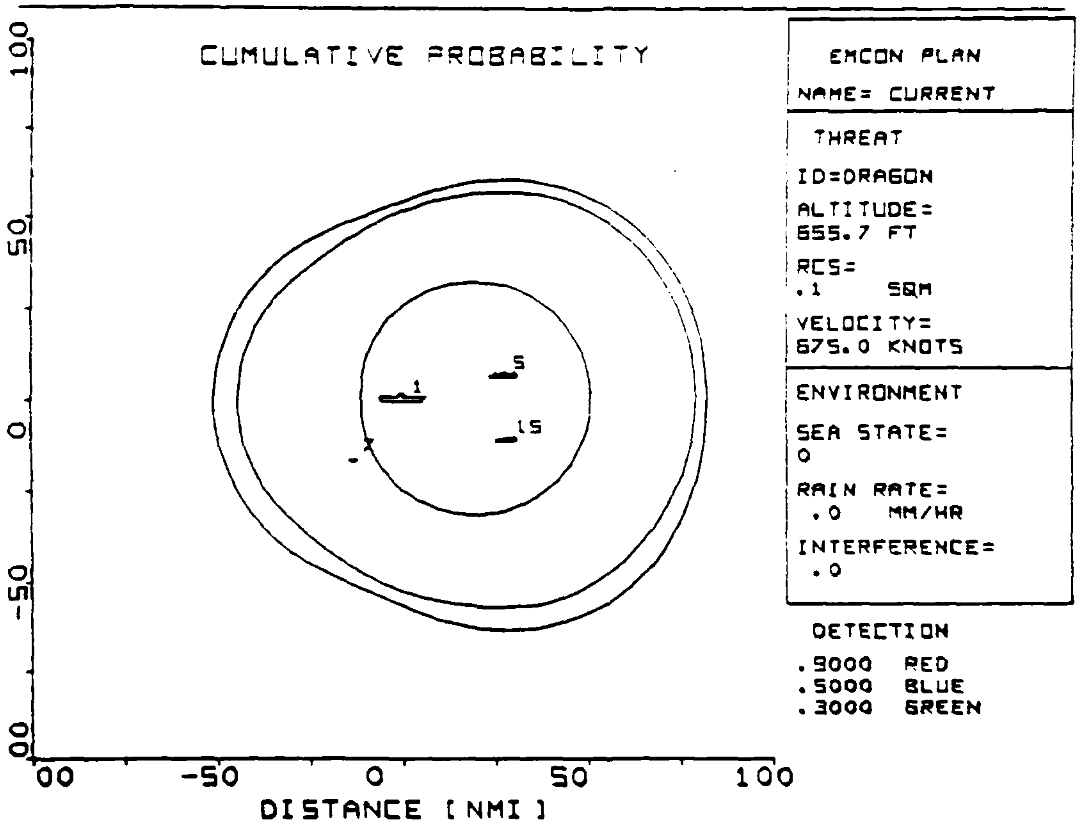



Figure 2-8. Cumulative Detection Probability Against a Dragon Cruise Missile Directed Radially Toward the High Value Unit. In this black and white copy of a color display, the red contour is the inner one and the green contour is the outer one.

summarizing the detection capabilities of the task group tactical search radars against the "Dragon" missile, an illustrative cruise missile with a normal flight altitude of 200 meters, a radar cross section of .1 square meters, and a velocity of 675 knots. The contours in this map indicate the distances at which the task group has a .3, .5, and .9 cumulative detection probability against a Dragon missile directed radially toward the high value unit. By combining the contributions from each of the tactical radars to give an overall coverage from the entire set of task group radars acting together, this chart is an overall display potentially more meaningful to an emissions control posture evaluation than are the capabilities of each radar individually. Like the "Orange Ship Detection, Localization, and Identification" circle above, these calculations may be applied to many different kinds of information warfare scenarios, and not just to the task force defense scenario.

Blue detection and track capabilities affect the overall performance measure by its influence on Blue threat interception capability. Figure 2-9 shows the interception capabilities of the task group area defense against two kinds of missiles, the subsonic low-altitude "Dragon" cruise missile, and a high-altitude supersonic "Rattler" missile.

In addition to calculating the consequences of an emissions control posture, the decision aid can provide the user with static information about the numbers and capabilities of friendly and adversary systems. This information is retrieved from the aid data base. Such static information is referenced by the two oblong shapes labeled "Orange (or Blue) Assets and Base Information Level."

### 2.2.2 Higher Level Influence Diagrams

Many different factors influence the output in all main level displays of Figs. 2-1 through 2-9. These factors are not shown in the main level diagram, but may be examined in the

EMCON PLAN = INFO

SURVEILLANCE SCORE -- INTERCEPTION PROBABILITIES

| THREAT NAME | INTERCEPTION PROBABILITY CURRENT PLAN | ALL ON | WEIGHT |
|---|---|---|---|
| RATTLER | 0.48 | 0.70 | 0.50 |
| DRAGON | 0.20 | 0.47 | 0.50 |
| SCORE | 0.34 | 0.58 | |

Figure 2-9. Blue Threat Interception Capability Against the Rattler and Dragon Missiles. This capability depends jointly on the early warning provided from the tactical search radars (Fig. 3-6) and on the quality of Blue interceptors.

higher level interface diagrams. In the interface there may be several levels of diagrams, each showing the increasing detail of continually more specialized factors. The number of different diagrams required to display these levels depends on a trade-off between a user preference for simple displays and a preference to have as much information as possible all in one place. For this discussion, all factors influencing each of the main level factors will be shown on a single chart.

The many factors displayed in these detailed interface diagrams may be qualitatively quite different from each other and from their corresponding main level display. For example, in Table 2-1, the main level display "Orange signal detection, localization, and classification capabilities" summarizes an overall capability. The influencing factors, on the other hand, may include the names of surveillance sensors or descriptions of suspected information warfare tactics. The aid combines these qualitatively different factors in many different ways to calculate an overall capability. For example, a particular specification of one factor may direct the aid to use one particular computational algorithm rather than another, while the specifications in another factor may provide particular values for equation parameters.

#### 2.2.2.1 Factors Influencing Orange Ship Inferences

Perhaps the most important and most complex of the detailed influence diagrams is the expansion for "Orange Ship Detection, Localization, and Identification" shown in Fig. 2-10. This chart indicates three important factors that affect what Orange may infer about the Blue task group disposition given a particular Blue emissions control posture. First, there is "Current Orange Situation Perception," the information about task group disposition obtained earlier in the information warfare. Second, there is Orange beliefs about U.S. doctrine, developed primarily from historical information and national intelligence. Third,

TABLE 2-1

ORANGE SIGNAL DETECTION, LOCALIZATION, AND CLASSIFICATION CAPABILITIES

| U.S. EMITTER | LOCALIZATION | DETECTION PROBABILITY | CLASSIFIED TO |
|---|---|---|---|
| SPS-10 | 10 nmi | 10% | AN SPS-10 |
| SPS-43 | .5 nmi | 90% | AN SPS-43 |
| SPS-52 | .05 nmi | 90% | A PARTICULAR SPS-52 SPS-52 |
| KH HULL | .5 nmi | 100% | A HULL NOT A SPECIFIC SHIP |
| KH PROPELLER | BEARING ONLY | 5% | 4 PROPELLER screw |

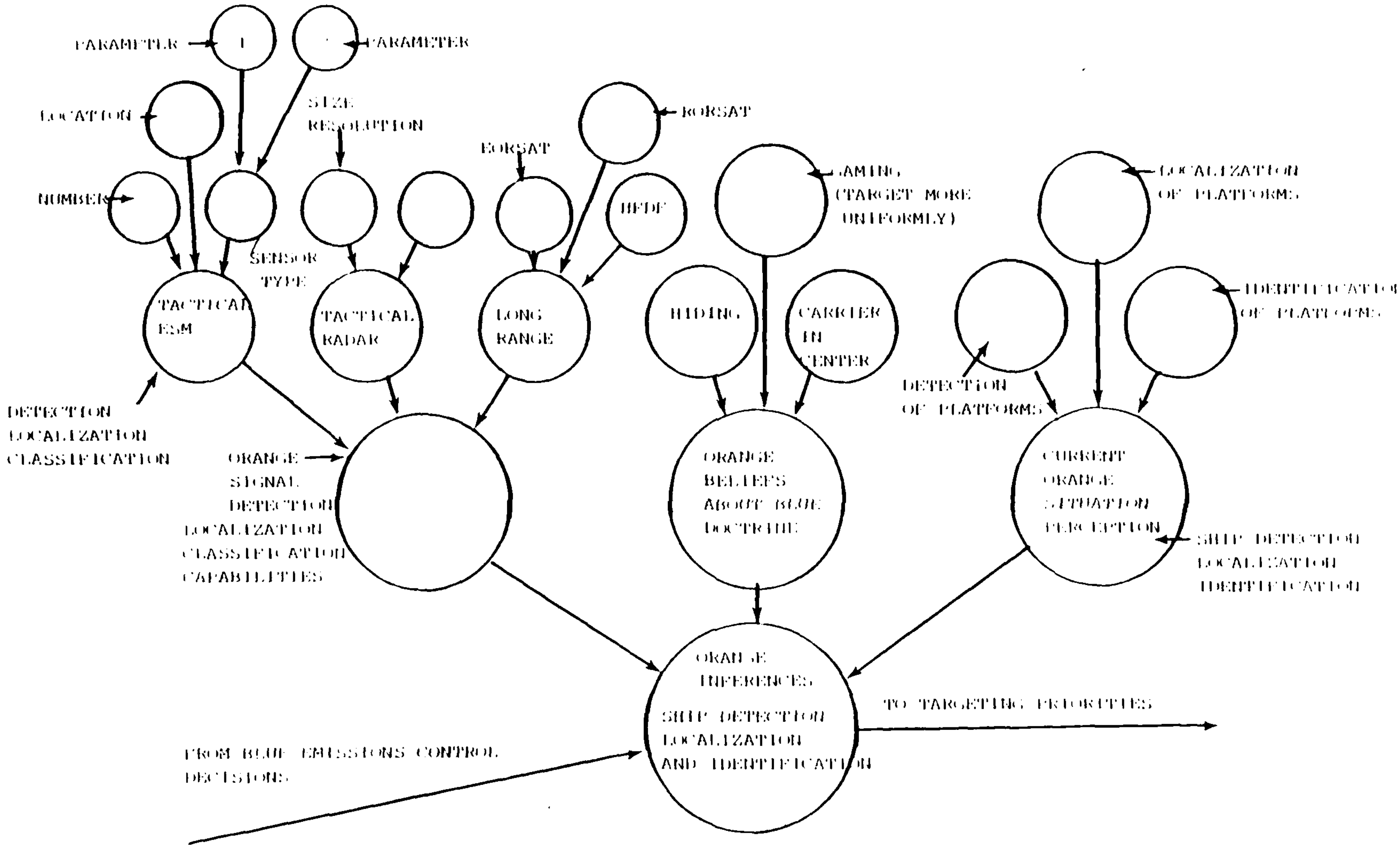



Figure 2-10. Interface Diagram Detailing Most Important Factors Affecting "Orange Inferences: Ship Detection, Localization and Identification"

there is the Orange surveillance capability--how well Orange would be able to detect, localize and classify Blue emissions.

Each of these factors may have major effects on the consequences of a Blue emissions control posture. For example, if Orange already knows the location and identity of every Blue platform, then emissions control postures designed to conceal the presence of task group ships or to deceive Orange about the identity of Blue platforms are unlikely to be effective. On the other hand, an unrestricted emissions posture is, in this case, unlikely to convey any information not already known by Orange.

The factor, "beliefs about U.S. doctrine" influences the interpretation Orange assigns to a pattern of Blue task group emissions. The diagram portrays three factors useful for categorizing "beliefs about U.S. doctrine." The factor "hiding" refers to a U.S. tactic to hide the high value unit either by selecting an emissions posture in which the high value unit emissions are inconspicuous, or in addition by having a posture in which lower value ships attempt to look like the high value unit. If Orange were certain that the U.S. were employing a "hiding" information warfare tactic, then he would infer that any platform emitting "carrier like" emissions is not the carrier. Thus, a Blue attempt to decoy Orange from the high value unit would fail.

Normally, Orange could not know Blue's information warfare tactic. Instead, he would assume that Blue would use different tactics on different occasions, and therefore Orange would assume that inferences which presupposed any one of these tactics would be unreliable. If Orange wished to adopt a conservative inference procedure, he would use an inference method that approximated a game solution to emissions control in information warfare. Such an inference algorithm would assume that the U.S. will use different information warfare tactics at different times and would produce ship identity inferences well-hedged against deceptive U.S. tactics. "Gaming" is the factor that reflects Orange's beliefs that the U.S. is employing deceptive "game like" mixed strategies. In the aid the gaming solution is approximated by an algorithm that assigns an equal probability of being the high value unit to every platform that could be the high value unit on the basis of the emissions profile and other evidence. For example, if out of seven platforms four had emissions consistent with the carrier, then each of these four is assigned a .25 probability of being the carrier.

A third kind of belief about Blue doctrine is "carrier in the center." If Orange believed that U.S. doctrine required that the high value unit not be on the task group periphery, then Orange would conclude that platforms near the center are much more likely to be the high value unit than platforms near the edge of the formation.

The demonstration aid tested in the formal evaluation used an Orange inference in which every task group ship disposition compatible with the emissions profile was assumed equally probable. This algorithm permitted highly successful deceptive emissions control plans in which Orange inferences about ship identity were completely wrong. As a result, these plans led to Orange strikes in which the high value unit was not targeted. Had these tests assumed a more conservative Orange algorithm, either by using a "gaming" algorithm or by evaluating platform identities using alternative inference algorithms that assume different U.S. hiding doctrines, these deceptive plans would have been less successful, and the Orange strike configurations would have been more credible. Because the aid outcome was so sensitive to the inference algorithm, DSA added alternative inference algorithms to the aid. These are discussed in Sec. 3.

The third major factor influencing the effect of Blue emissions posture on Orange inferences about Blue platforms is the ability of Orange to detect, localize, and classify these emissions. Like the other two second level influences, this effect can dominate the information conveyed by task group emissions under certain conditions. For example, if Orange cannot detect any Blue emissions, then no emissions posture will convey any information about the Blue task group. If, on the other hand, Orange not only can detect every Blue emission but can also fingerprint; i.e., do a hull-to-emitter correlation, then every radiation source permits Orange to detect, localize, and identify the source's platform.

The Orange capability to detect, localize, and classify Blue emissions depends on the capabilities and coordination of their surveillance sensors. Three sensor classes contribute to the overall Orange signal detection, localization, and classification capability: long-range sensors, tactical radars, and tactical passive sensors. Long-range sensors are not normally under the control of the tactical commander. The tactical surveillance systems are electronic surveillance measures (ESM) and radars within a few hundred miles of the task group. The capabilities of these systems may be specified in terms of fundamental engineering parameters such as signal-to-noise sensitivity, or they may be specified in such operational terms as their ability to resolve differently sized objects. The diagram is organized according to the kind of information that the aid user would need to provide the aid in order for it to calculate the detection, localization, and classification capabilities of the aggregate systems. For surveillance sensors currently specified in the aid data base, this information would be the name of the sensors and their positions relative to the task group. For sensor types not in the aid data base, the needed information would be the fundamental engineering specification of the sensors and their positions.

2.2.2.2 Factors Influencing Targeting Priorities

The circle "Targeting Priorities" in Figs. 2-1 and 2-11 represents the importance assigned by Orange to each detected platform. These priorities depend only on the perceived ship identity for each platform, and on "Assigned Ship Values," the mission dependent value assigned by Orange to each ship.

2.2.2.3 Orange Strike Specification

Figure 2-11 details the factors required to specify the Orange missile strike. The strike specification depends both on available Orange weaponry and also on the rules for assigning weapons to the target platforms for the attack. Each missile type is characterized by its altitude, velocity, accuracy, yield, radar cross section, and permissible launch zones.

These types and numbers of available missiles constrain the Orange strike. A strike may use only those missiles that are available, must launch these from permitted launch zones, and must employ them at their design velocity and altitude. The actual strike, however, depends on how the selected assignment algorithm allocates these missiles. The demonstration aid, for example, included two different automated assignment algorithms. One algorithm assigned missiles to each platform in direct proportion to the perceived value of that platform. The second algorithm assigned missiles so as to maximize the total expected task group value destroyed, taking into account the quality of defense about each platform and the diminishing return from each missile assigned to the platform. Both algorithms selected the best attack bearing consistent with the permissible launch zones.

The user interface diagram for Orange strike specification is far more scenario specific than the interface diagram for Orange ship identity inferences. The aid calculations of adversary ship identity inferences are applicable to many information warfare problems and not only those concerned with task group defense against a surprise missile attack. In

ORANGE STRIKE SPECIFICATION

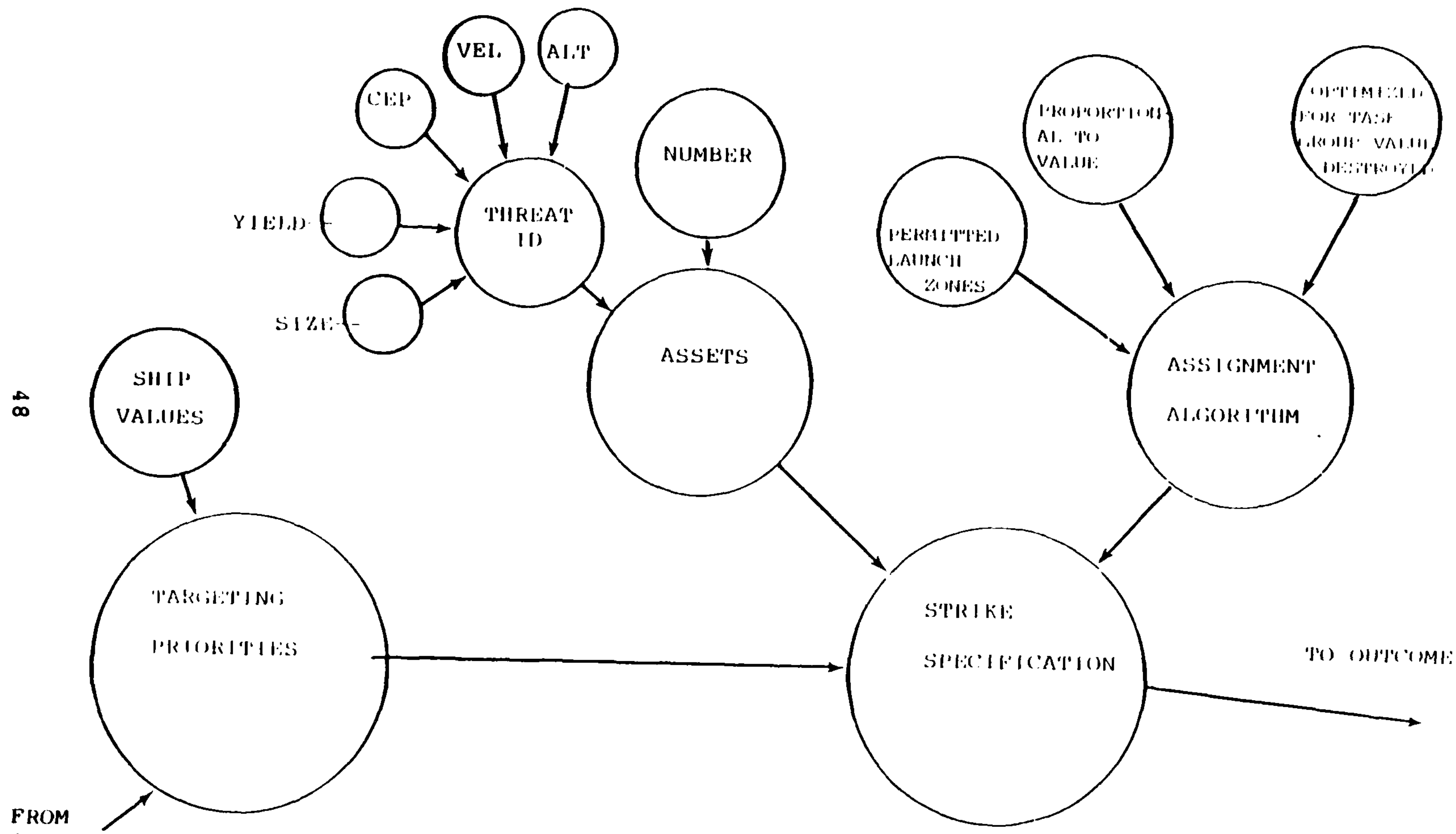



Figure 2-11. Factors Required to Specify Orange Missile Strike

contrast the Orange strike specification is much less broadly applicable. It assumes the defense scenario, and includes only those kinds of air defense strike factors that may be considered by the aid.

2.2.2.4 Blue Detection and Track Diagram

Figure 2-12 details the factors which affect the quality of the Blue tactical surveillance. Each of the three main factors in this diagram--radar coverage, detection by passive ESM, and system interactions--are tactical systems. Long-range systems can improve Blue detection and tracking by providing early warning. Their effects act indirectly through the alert status of the tactical systems, and are represented in this diagram by the factor "manning."

Detection and track capabilities of each task group tactical radar depend both on inherent radar capabilities, and on the threat characteristics. In this diagram, the factor "Threat ID" identifies the threat type. For threats in the aid data base specification of the threat name suffices to specify to the aid all threat characteristics needed for calculating threat detectability. In EWAR these parameters are threat size, altitude, velocity, and attack direction. Similarly, the factor "radar ID" identifies radar type. The aid data base includes, for each radar type, all factors which influence the inherent capabilities of a radar to detect and track missiles. Specific factors included in the EWAR model are radar antenna height, needed to calculate the radar horizon; radar power, which determines the strength of a reflected signal from a "standard" target under standard conditions; radar manning levels, which determine how carefully the radar scopes are monitored; and radar frequency, which is critical when some frequencies are jammed or when many nearby radars are active simultaneously.

Passive sensors often give the earliest warning of a surprise attack. Whenever the attacker is electronically active,

EMISSIONS CONTROL FOR TASK FORCE DEFENSE

BLUE DETECTION AND TRACK

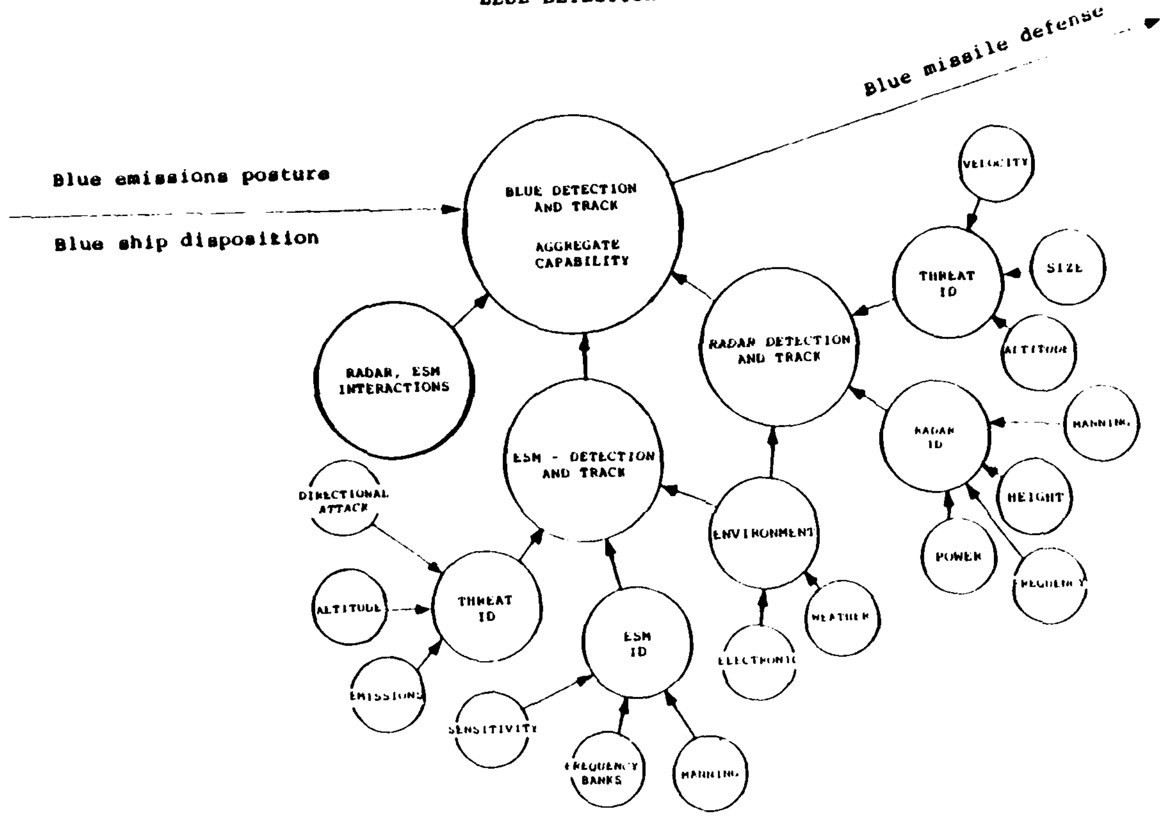



Figure 2-12. Interface Diagram for Blue Detection and Track Capability

tactical electronic surveillance measures (ESM) are likely to detect the attacker before the attacker can detect the task group, and usually before task group radars can detect the threat. The items "Threat ID" and "ESM ID" identify the threat and ESM equipment.

Both radar and ESM capabilities depend on the environment. In this diagram the two environmental factors are "weather" and "electronic." Weather includes sea state, rain rate, and atmospheric ducting. Electronic includes diverse electronic countermeasures from the attackers.

The two factors "ESM detection and track" and "radar detection and track" summarize performance capabilities for each separate surveillance system. The aid computes an aggregate surveillance capability by combining the contributions from these separate systems. Because these systems sometimes support and interfere with each other, the aggregate capability can be a complex function of the individual capabilities. For example, two radars searching the same areas will support one another if their frequencies are sufficiently different. If their frequencies are nearly the same, however, nearby radars may interfere with each other but sufficiently separated radars may support one another. The interactions between ESM and active radar search are similarly complex. Blue radar activity may preclude ESM search at similar frequencies. With sufficient space or frequency separation, simultaneous use of both radar and ESM may be possible.

#### 2.2.2.5 Blue Threat Interception Capability

This interface diagram, Fig. 2-13, like the Orange strike configuration diagram, contains only elements for the air defense scenario considered by the aid. Besides Blue detection and track capabilities, the area defense quality, the point defense quality, and the size and type of the threat influence the overall Blue defense capabilities. Two types of area defense are

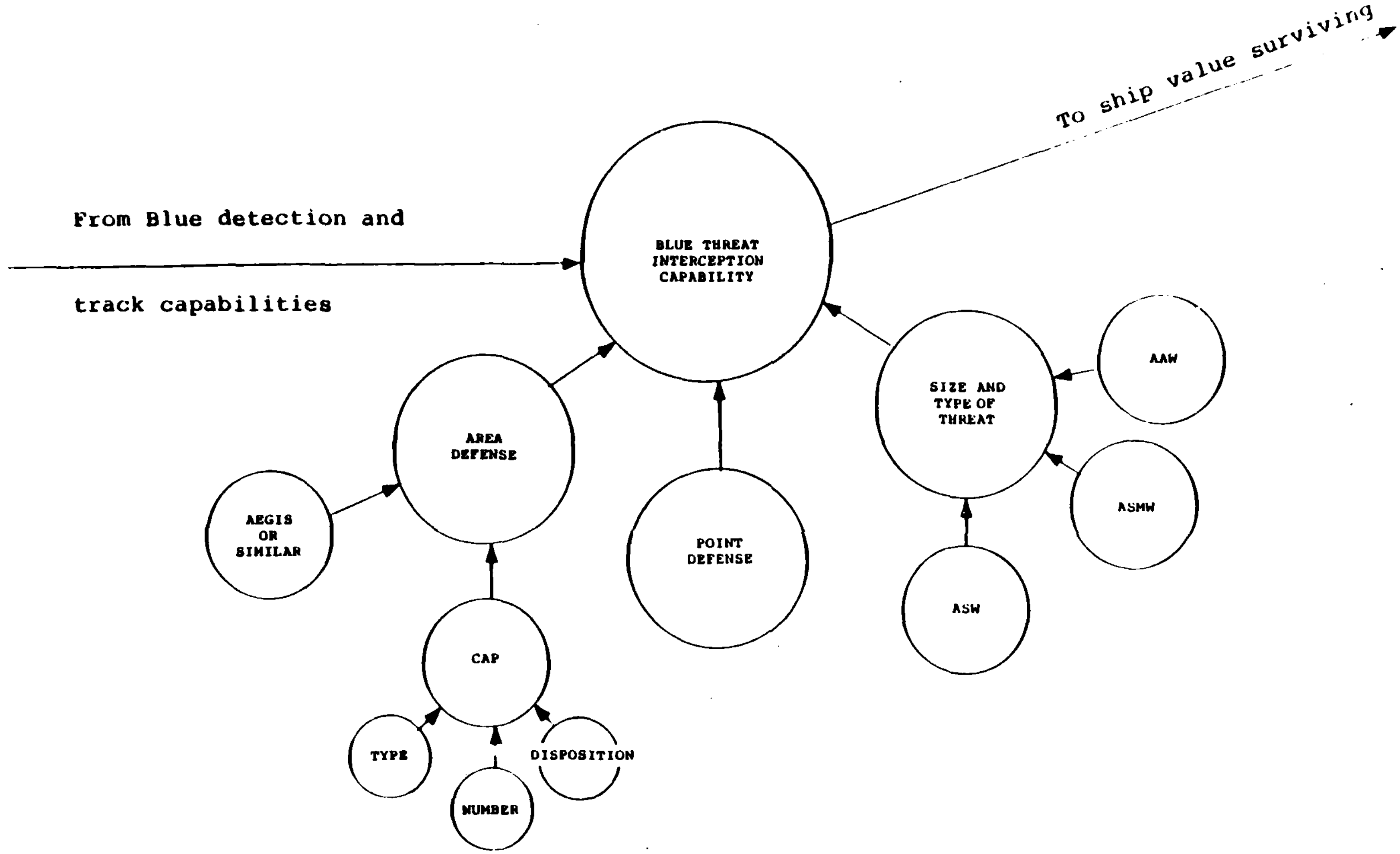



Figure 2-13. Interface Diagram for Blue Threat Interception Capability

specified: a coordinated area missile defense such as AEGIS, and the combat air patrol (CAP).

## 2.3 INTERFACE COMMAND STRUCTURE

The hierarchical interface diagrams previously discussed display the aid structure to the user and permit him to efficiently assess variables of current interest. The interface commands permit the user to operate on factors identified in the interface diagram. Except for the command to enter the interface, each of the interface commands assumes that an interface diagram is being displayed. The response to each command will depend jointly on the specific command and on the designated interface factor design.

The command INTERFACE displays the main level diagram, Fig. 2-1, and activates the aid interface. Once in the interface the user may enter commands related to a desired factor by positioning a pointer within the circle for that factor and typing one of the six commands that trigger a desired interface function.

### 2.3.1 EXPLAIN Command

The EXPLAIN command produces on the display information describing the factor designated by the pointer. This command concerns only static information of the sort that would appear in the aid user's manual. Dynamic information dependent on the current state of the aid is elicited by the other interface commands. In general, the information displayed briefly defines the variable and refers the user to the appropriate page in the user's manual for a more complete discussion.

For example, if the user wished additional information about permitted launch zones he would position the pointer in the circle labeled "Permitted Launch Zones" in the Orange Strike Specification diagram and type EXPLAIN. On the display would appear the message:

> Launch zones permitted by the aid must be beyond the task group radar horizon. The user may select the missile attack bearing or a range of permissible attack bearings.

These may be different for each missile type against each target.

Typing a carriage return replaces the message with the interface diagram last displayed.

If the user wished for an explanation of the main level factor "Orange Inferences--ship detection, localization, and identification," he would type the command "EXPLAIN" with the pointer positioned within the corresponding circle in the main level diagram. The interface would print the message:

> Projected Orange ship inferences based on assumed prior ship knowledge, beliefs about U.S. doctrine, and assumed Orange surveillance posture. See page 48 in manual for additional information.

2.3.2 The SHOW Command

The SHOW command displays the current values associated with the factor selected in the currently displayed interface diagram. The display format depends on the factor. For example, if the user types SHOW with the pointer in any of the main level diagrams, the display output is the appropriate calculated aid display, Figs. 2-1 through 2-9.

The following examples show how the kinds of information displayed by the SHOW command changes as the diagram level changes. The values displayed in these examples are intended only to illustrate the display format; they were not produced by the interface. Figure 2-2 showed the output from the main level factor "Orange inferences--ship detection, localization, and identification." That figure indicated the probability that each task group platform will be detected and the precision with which it is likely to be classified. These numbers are computed by the aid and depend on the Blue emissions posture, on previous Orange inferences about the task group, on current Orange beliefs about U.S. doctrine, and on the ability of Orange to detect, localize, and classify Blue emissions.

If the user wished to review the current aid assumptions about Orange surveillance capability, he would use the SHOW command with the pointer in the "Orange signal detection, localization, and classification capabilities" circle. The interface would generate a display as shown in Table 2-1 (duplicated here for convenience).

Table 2-1 shows the vulnerability of each U.S. emitter to the totality of Orange surveillance resources. It indicates, for example, that any emitting SPS-10 has only a 10% chance of being detected, can be localized only to an area of 10 nmi, and can be classified by type of radar. On the other hand, the table indicates that any emitting SPS-52 will most likely be detected, will be highly localized, and will be fingerprinted to a particular radar.

The aggregate Orange signal detection, localization, and classification capability depends on the combined capabilities of his tactical passive sensors (tactical ESM), on his tactical radar, and on his long-range sensors. If the user wished to know what signal vulnerabilities the aid was attributing to each of these classes of sensors, the user could use the SHOW command with the pointer in one of the next level factors. The aid interface display of signal vulnerabilities to tactical ESM may be as shown in Table 2-2.

As Table 2-2 shows, tactical ESM cannot detect the Kitty Hawk hull or the SPS-10 radar. The SPS-52 can be localized along a bearing.

The overall surveillance capability of tactical ESM sensors is the aggregate capability of these sensors individually. As currently designed, the aid interface would not display the overall surveillance capabilities of each sensor (though this information becomes available by temporarily deleting all sensors

TABLE 2-1

CRANGE SIGNAL DETECTION, LOCALIZATION,
AND CLASSIFICATION CAPABILITIES

| U.S. EMITTER | LOCALIZATION | DETECTION PROBABILITY | CLASSIFIED TO |
|---|---|---|---|
| SPS-10 | 10 nmi | 10% | AN SPS-10 |
| SPS-43 | .5 nmi | 90% | AN SPS-43 |
| SPS-52 | .05 nmi | 90% | A PARTICULAR SPS-52 SPS-52 |
| KH HULL | .5 nmi | 100% | A HULL NOT A SPECIFIC SHIP |
| KH PROPELLER | BEARING ONLY | 5% | 4 PROPELLER screw |

TABLE 2-2

ORANGE SIGNAL DETECTION, LOCALIZATION, AND CLASSIFICATION CAPABILITIES BY ORANGE TACTICAL ESM

| U.S. EMITTER | LOCALIZATION | DETECTION PROBABILITY | CLASSIFIED TO |
|---|---|---|---|
| SPS-43 | .5 nmi | 90% | AN SPS-43 |
| SPS-52 | BEARING ONLY | 90% | A PARTICULAR SPS-52 |

but one). Rather, at the next level the interface is concerned with the kinds, numbers, and deployment of Orange sensors. Using the SHOW command with the pointer at the next level gives a list of the names, locations, and numbers of each sensor. Thus, the display output for this level has the form shown in Table 2-3.

The most detailed level of the diagram concerns the engineering specification of the separate sensors. The interface display for a SHOW command at the parameter specification level is shown in Table 2-4.

2.3.3 SET Command

The SET command is used to set parameters to values desired by the user. This command has two effects. First, it sets planning factors to those desired by the aid user. Second, when applied to parameters normally calculated by the aid, it overrides the internal aid calculations that determine more aggregate qualities from more detailed and fundamental parameters. The dual function of the SET command is illustrated by its various effects on parameters of different levels in the interface diagram for "Orange Signal Detection, Localization, and Classification."

The most detailed level specifies the engineering parameters that determine the capabilities of Orange sensors. Using the SET command at this level produces a display very similar to that produced by the SHOW command, as seen in Table 2-5.

At the next level the SET command is used to specify the types, locations, and numbers of Orange surveillance sensors. If the user specifies sensors of a type known to the data base, then he does not also need to specify the engineering factors. The aid will instead assume that the specified sensor will have its usual capabilities.

TABLE 2-3

ADVERSARY SENSOR TYPES AND LOCATIONS

| Sensor Type | Location (relative to KH) |
|---|---|
| Bear D | 200 nmi at 270° |
| Bear D | 140 nmi at 140° |
| Picket submarine | 30 nmi at 80° |

TABLE 2-4

SENSOR ENGINEERING SPECIFICATION

| | |
|---|---|
| Sensor sensitivity: | 27 db |
| Frequency: | J band |
| Localization discrimination: | .5° |

TABLE 2-5

DISPLAY FOR SPECIFYING SENSOR CAPABILITIES

| | Current Value | New Value |
|---|---|---|
| Sensor sensitivity: | 27 db | (entered |
| Frequency: | J band | by |
| Localization discrimination: | .5° | user) |

The next higher level is the aggregate Blue signal vulnerability from all Orange tactical ESM. The user may specify these values directly, or he may prefer to permit the aid to compute them from the sensor information. If the user specifies these values, then the aid will assume that these aggregates supersede those computed by the aid from the sensor information. The user may wish to override these calculations either to explore emissions control consequences for different possible parameterized surveillance capabilities or to input data from alternative sources. In the latter case, the SET command frees the planner to evaluate emissions control consequences using some calculations from the aid and other calculations from other Navy systems.

As for the previous level, the SET command applied to "Orange signal detection, localization, and classification capabilities" will override more detailed aid calculations. Specifying these aggregate values insures their use in the aid calculations of the Orange ship inferences from Blue emissions, from the specified Orange beliefs about Blue doctrine, and from previous Orange information about the task group.

Use of the SET command at the main level fixes factors that normally depend on the Emissions Control Posture. The command SET with the pointer at the main level factor "Orange Inferences: Ship Detection, Localization, and Identification" produces the display in Table 2-6.

Fixing these values decouples the Orange inferences from the emissions control posture. A planner might wish to do this, for example, to distinguish the emissions control consequences to ship damage due to Blue surveillance capabilities from the effects due to the information given away.

TABLE 2-6

SPECIFYING THE AGGREGATE ORANGE CAPABILITIES TO DETECT, LOCALIZE AND CLASSIFY BLUE PLATFORMS*

| Platform | Probability of Detection Current | Probability of Detection New | Localization Current | Localization New | Classification Ship | Classification OLD Probability | Classification NEW Probability |
|---|---|---|---|---|---|---|---|
| KITTY HAWK | .99 | .99 | .01 | .01 | KH | .125 | .33 |
| | | | | | CHIC | .125 | .33 |
| | | | | | GRID | .25 | .33 |
| | | | | | VIREO | .5 | 0 |
| CHICAGO | .99 | .99 | .01 | .01 | KH | .5 | .33 |
| | | | | | CHIC | .5 | .33 |
| | | | | | GRID | 0 | .33 |
| | | | | | VIREO | 0 | 0 |
| GRIDLEY | .99 | .99 | .01 | .01 | KH | .25 | .33 |
| | | | | | CHIC | .25 | .33 |
| | | | | | GRID | .25 | .33 |
| | | | | | VIREO | 0 | 0 |
| VIREO | .99 | 0 | .01 | .01 | KH | .125 | 0 |
| | | | | | CHIC | .125 | 0 |
| | | | | | GRID | .25 | 0 |
| | | | | | VIREO | .5 | 0 |

---

*In this table, the user specifies that the Vireo is not detected and that the adversary cannot classify each of the three remaining platforms.

### 2.3.4 SENSITIVITY Command

The SENSITIVITY command computes the sensitivity of the emissions control decision to a parameter value or model assumption. For example, suppose that the planner wishes to assess the sensitivity of emissions control plan choice to the adversary's a priori probability that the carrier is near the task group center. By placing the pointer in the "carrier in center" circle in Fig. 2-10, and specifying the SENSITIVITY option with parameter "High Value Unit Centered," and parameter values .25 and .5, the user elicits the display shown in Table 2-7.

Table 2-7 lists the expected task group fractions surviving a previously specified air strike for two different EMCON postures and two different parameter values. Plan INFO is the aid-calculated emissions control plan designed for maximum deception, and plan ALL ON, the emissions posture with all search radars emitting, provides maximum task group surveillance coverage. The aid user could select other emissions control plans for use in the SENSITIVITY command. These two are the default plans because they represent two "bounding" emissions control postures. In this example, the carrier is placed near the periphery. Thus, adversary targeting which supposes a centered carrier increases task group survivability.

At the bottom of the table is the parameter value that would be required for a decision change, .36. If the adversary's a priori probability for the carrier being near the center exceeds .36, then plan INFO is preferred. For lower probabilities plan ALL ON would be preferred. This sensitivity display indicates that EMCON plan choice is sensitive to this factor, and the planner should take into account this inherent uncertainty in his planning.

TABLE 2-7

SENSITIVITY DISPLAY FOR ADVERSARY'S A PRIORI PROBABILITY THAT CARRIER IS NEAR THE TASK GROUP CENTER

| | P = .25 | P = .5 |
|---|---|---|
| Plan INFO | .312 | .625 |
| Plan ALL ON | .45 | .45 |

Parameter value for decision change: .36*

---

*In this example, the adversary uniquely identifies the carrier if plan ALL ON is adopted. Therefore, the outcome is independent of any prior assumptions of carrier locations. With plan INFO, he must infer carrier position. Since in this example, the carrier is not near the task group center, task group survivability improves as the adversary is increasingly inclined to presuppose that the carrier is near the formation center. When the adversary's prior probability is .36, the two EMCON plans INFO and ALL ON are equally effective. Table entries are task group fraction surviving an attack given specified EMCON status and a priori probability that carrier is near task group center.

It is, of course, possible (and even likely) that other emissions control plans are better than plan ALL ON in this scenario, and the aid user might wish to search for such plans. Moreover, it is likely that the assumed a priori probability for the carrier being near the center is critical to the choice of emissions control plan. Since the decision between two "extreme" plans such as ALL ON and INFO is so sensitive to this factor, the choice between two more similar plans may also be sensitive to the adversary's a priori probability that the carrier is near the formation center.

Note that the SENSITIVITY command tests for the sensitivity of a decision to a parameter value. It does not test the sensitivity of the chosen outcome measure of effectiveness to these values. The distinction between testing the sensitivity of the decision itself rather than the measure of merit reflecting the outcome quality is essential in understanding the value of this command. The purpose of decision aids is to improve the quality of decisions. If, for example, there existed a best decision, then a perfect aid would always lead the user to this decision. It is possible that the calculations in this perfect aid are not extremely accurate, and may omit many details that are not pertinent to the decision though they may seem that way superficially. If these details can affect the selected measure of merit, then the accuracy of the computed measure of merit in such a perfect aid may not be fully accurate. Nevertheless, in such a perfect aid this computed measure would be sufficiently accurate to guide the user to the best decision available. For example, it is possible, in this perfect aid, that there exists parameters that exert major influences on the outcome measure for each examined plan, but exert these influences uniformly for all plans. Thus, the preferred decision would be insensitive to the factor despite its apparent effects on the outcome measure. A trivial example of such a factor would be a scaling multiplier for the output table. Some users may prefer their outcomes scaled from zero to one; others may prefer a zero to one hundred scaling. If a parameter existed that changed the outcome units from one to the other, then the outcome measure would be extremely sensitive to such a parameter while the decision choice would, of course, be totally indifferent to it.

### 2.3.5 EXPAND or CONTRACT Commands

These final two commands permit the user to access diagrams at different levels in the interface. For example, using the EXPAND command with the pointer in the main level factor "Orange Inferences: ship detection, localization, identification" changes the display from the main level diagram (Fig. 2-1) to the more detailed diagram of Fig. 2-10. Similarly, using the CONTRACT command changes the display from a more detailed diagram to the next higher diagram. Thus, the command CONTRACT with the pointer in "ORANGE signal detection, localization, and classification capabilities" changes the display from Fig. 2-10 to the main level display.

## 2.4 USING THE INTERFACE

The introduction to this section listed six different questions which the interface is intended to address. The following discussion indicates how the different interface features outlined previously can help answer these questions.

### 2.4.1 How Do I (the User) Know that the Aid Considers All Factors That I Think Are Important?

Both the interface diagrams themselves and the SENSITIVITY and EXPLAIN commands help to answer this question. The diagrams show those factors potentially important to the emissions control decision, including both factors currently modeled by the aid and factors not included in the aid. The EXPLAIN command outlines how the aid treats the factor. The SENSITIVITY displays help evaluate how the aid treats these factors.

If a factor believed by the user to be important is either not included in the interface diagram or is identified in the EXPLAIN command as not currently incorporated into aid calculations, then the user is alerted to possible limitations of aid applicability to his current needs. It is possible, even in this case, that the aid may still be useful if the user is able to manually adjust the aid-supplied output to reflect the missing factors, if the user determines through the SENSITIVITY command that this factor actually is relatively unimportant, or if the user can integrate some aid calculations with others already done using a different available system. In using the SENSITIVITY command for this application, the aid user selects a factor in the diagram that he believes would be affected by the factors not modeled in the aid. He next estimates bounds on the possible effects of the missing factors on the values of the factor included in the aid. Finally, using the SENSITIVITY command he determines the possible effects on the decision choice of the missing factor. If he sees that this effect is large, he may decide that the aid is not a useful tool for this present application. On the other hand, if he sees that the effects are small, he may decide that the aid is, after all, of value for the scenario of current interest.

On the other hand, if the factor is included in the diagram, it still may not be influencing on output properly. If the user is certain that a factor is important in a particular situation, he may use the SENSITIVITY test on this factor to determine its effect on the outcome. A small effect would suggest that the factor is not affecting the outcome properly.

### 2.4.2 Although I Am Assured that the Aid Considers these Factors, How Do I Know They Are Modeled Appropriately for My Needs?

Sometimes the interface indicates that the aid does consider a factor thought by the user to be important to the current decision and the sensitivity test indicates an effect of the proper magnitude, but the user is still uncertain whether the aid actually does consider it appropriately for his needs. Both the hierarchical structure of the aid itself and the interface are designed to help a user assess the validity of the aid calculations. The aid hierarchy as described in a previous DSA report, An Emissions Control Decision Aid, DSA Report No. 66, July 1978, does so by allowing the user to trace the calculation results from more simple to more complicated displays.

The interface diagrams and the EXPLAIN and SENSITIVITY commands also help the user assess the validity of the aid. The interface diagrams suggest the actual mechanisms by which the aid incorporates different factors to calculate emissions control quality. The user may determine whether these mechanisms are appropriate for each particular aid application. The EXPLAIN command references the user's manual's explanation of each factor. This detailed description will frequently be sufficient for the user to determine whether the aid treats a factor appropriately for a particular application. The SENSITIVITY command provides a double check. If the user is certain that a factor will affect the outcome in a particular way he may use the SENSITIVITY command to determine whether the aid's calculations confirm his expectations. If it does not, then the user should be cautious about using the aid. If the sensitivity test indicates appropriate behavior, then the user may be more confident in the aid outcome calculations.

### 2.4.3 I Am Not Sure what Value to Assign to a Planning Factor. Should I Go to Much Trouble to Find the Appropriate Value?

The aid requires values of many different planning factors for its computations of emissions control quality. Determining accurate values for these many parameters may be a significant burden to a user. Accurate values for most of these planning factors, however, are not required for most aid functions. The SENSITIVITY command can help the user to determine which of these planning factors require accurate values, and how precise these values should be. If the sensitivity check indicates that the decision choice is insensitive to large changes in the value of a factor, then there is little need to determine its value accurately. If, on the other hand, the values of some factors strongly influence the decision choice, then the user should input these values carefully.

2.4.4 What Value Does the Aid Currently Assign to Planning Factors?

The user may use the SHOW command to review the aid planning factor values. These include both those planning factors explicitly input by the user, those that are default values assumed by the aid, and those that are computed by the aid from the values of more basic parameters. The aid interface, which shows the hierarchy of possible planning factors used by the aid, indicates which of the planning factors input by the user would be used in calculating each of the more aggregated factors used for the higher level calculations of emissions control quality. These diagrams also show which detailed parameters are overridden whenever the user specifies the values for the higher level factors directly.

2.4.5 I Do Not Understand the Diagrams in this Interface. What Do these Diagrams Mean?

The EXPLAIN command describes each of the factors in the interface diagram. The user's manual describes the general interpretation of the diagram, explaining the meaning of the symbols and the arrows connecting the different factors.

2.4.6 I Believe Accurate Values for Planning Factors Are Required. How Can I Estimate these Values?

The interface design was motivated largely by the requirement to help aid users obtain and input the values of needed planning factors. The interface can do so either by calculating values of higher level factors from more detailed factors that may be easier to estimate, or by facilitating the proper incorporation of parameter values obtained from other shipboard systems.

An example of how the interface helps the user to estimate the values for some of the planning factors needed to calculate "Orange ship detection, localization, and identification" may clarify this application of the interface. The aid computes

Orange ship detection estimates from four kinds of information: Orange prior beliefs about Blue task group disposition, Orange beliefs about Blue doctrine, the emissions from the Blue task group, and Orange's capability to detect, classify, and localize these emissions. This example will focus on planning factors required for the last category. The information required to summarize the adversary surveillance capabilities, illustrated in Table 2-1, is the aggregate adversary capability to detect, localize, and classify all emissions.

If the needed estimates of adversary surveillance capability are available from another Navy system, it may be unnecessary for the planner to estimate the values in this table. For example, the Classic Fox program, which is concerned with vulnerabilities of U.S. signals to adversary surveillance, may in the future develop a system that provides a real time summary of aggregate adversary surveillance capability. If this system were available, then it could provide the aid with the required information.

If the planner must input accurate information not obtainable elsewhere, then he may use the aid interface to help estimate planning factor values. Of course, the user may choose to estimate the aggregate Orange signal detection, classification, and localization capabilities directly. If estimating these aggregate capabilities seems too difficult, however, he could instead estimate the aggregate Orange surveillance capabilities for the three separate systems of tactical ESM, tactical radar, and long-range systems. If he provides the interface with these summary data, then the aid will combine the surveillance capabilities from each of the three systems to provide the desired overall aggregate capability.

If the planner does not wish to estimate these aggregate capabilities from the adversary tactical active and passive sensors and from the long-range sensors, then he may instead permit the aid to compute these estimates from more fundamental data. In this case he inputs to the aid his estimate of the types, numbers, and locations of the different surveillance sensors. The aid will compute the aggregate capabilities from these data for those systems whose performance capabilities are included in the data base. For those sensors unknown to the aid, however, the user would need to specify those sensor engineering specifications relevant to task group surveillance. The interface would then compute both the capabilities of each described sensor, and also the aggregate capabilities from the totality of sensors.

## 2.5 AID INTERFACE WITH OTHER NAVY SYSTEMS

A decision aid is usually only one of many systems concerned with different facets of related problems. To be fully effective, the aid must interact efficiently with these other systems. It should, whenever possible, accept as inputs the outputs from such related systems, and its output should be useful as inputs to still other devices or staff functions.

The EWAR user interface facilitates integrating the emissions control decision aid with staff functions and other shipboard systems. Such integration both increases the value of the aid by permitting it to fit easily into task group operations and also increases the value of other systems by linking their performance calculations to an overall task group mission objective. This section will show how three different illustrative command and control systems interface with the aid.

### 2.5.1 Relationship to the Integrated Refractive Effects Prediction System (IREPS)

IREPS was demonstrated aboard the Kitty Hawk during the first set of interviews.[1] This system computes the

[1] H. V. Hitney and R. A. Paulus, Integrated Refractive Effects Prediction System (IREPS), Interim User's Manual, Naval Ocean Systems Center, San Diego, California.

effectiveness of a single radar in detecting incoming threats. It considers many more factors in its calculations than does the radar module in the aid, including in particular the effects of atmospheric ducting as determined by atmospheric soundings.

The interface diagram, "Blue Detection and Track Capabilities," Fig. 2-12, displays the major factors considered by the Emissions Control Decision Aid in computing the aggregate Blue capability. The aid radar module includes a radar detection and track model, an ESM detection and track model, and algorithms for computing overall capabilities given a total set of sensors which, depending on the circumstances, could either support or interfere with one another. The shipboard demonstration of IREPS suggested a possible synergy between IREPS and the aid. IREPS can predict the performance of individual radars much more accurately than can the simple models within the aid, but cannot integrate the effects of many radars or radars and ESM simultaneously. Because EWAR does such integration, it could accept the IREPS output calculations in place of its current Radar Detection and Track module to calculate a more accurate estimate of aggregate Blue detection and track capability.

### 2.5.2 Interface with Classic Fox Program

Classic Fox is a program concerned with assessing the vulnerabilities of U.S. signals to Soviet sensors. The Classic Fox general program objective is to calculate the ability of particular Soviet sensors to detect, localize, and classify U.S. emissions. As Fig. 2-10 indicates, this is just the information required for the aid calculations of Orange ship identification inferences. Unlike the aid, however, the Classic Fox systems will probably not be able to integrate the sensor capabilities with prior adversary tactical information and adversary knowledge of Blue doctrine and mission to provide an estimate of the useful tactical information that may be conveyed by a pattern of task group emissions. Thus, like IREPS, the Classic Fox program may provide superior estimates of inputs required by the aid, but be unable to integrate these estimates with other factors to calculate some of their operationally significant implications. The aid, by performing such calculations, may increase the value of the Classic Fox output.

### 2.5.3 Interface with Air Defense Calculators

Modern integrated task group defense systems, such as AEGIS, may have their own threat penetration predictions models. These models compute overall task group defense capabilities against specific threats using models both more detailed and better calibrated to actual capabilities than those in EWAR. These system-specific air defense models fit into the aid interface in the Air Defense module pictured in Fig. 2-13 with a threat specified in Fig. 2-11. By integrating the system-calculated air defense predictions with the aid's calculations of Blue surveillance capabilities and the adversary task group targeting capabilities, the aid can project an overall air defense related task group vulnerability associated with an emissions control posture.

## 3.0 EMISSIONS CONTROL FOR INFORMATION WARFARE

In addition to developing the new interface, DSA added two capabilities identified to be particularly important during the interviews and formal aid evaluations--automatic aid calculation of the maximally deceptive EMCON plan and increased flexibility in calculating Orange inferences of ship identities. During the formal aid evaluations the maximally deceptive plan was frequently the first to be evaluated and often became the "baseline" plan to which other plans were compared. Section 3.1 describes the algorithm for calculating this plan automatically. Section 3.2 discusses at length the importance of Orange assumptions about probable Blue emissions control tactics and emissions control planning in the information warfare environment. Because these wargaming considerations are so important, DSA modified the computational algorithms concerned with Orange ship identity inferences to enable them to reflect Orange assumptions about U.S. information warfare tactics.

### 3.1 AUTOMATIC CALCULATION OF PLAN "INFO"

Emissions control plan INFO is the standard plan which results in maximum deception against an adversary who assumes that every placement of task group ships consistent with the observed emissions is equally probable. When using the aid, it is frequently convenient to use INFO as a standard baseline and to search for improved plans by adding those radars which most improve task group surveillance while conveying the least additional targeting information. Because plan INFO is so useful, many participants in the formal aid evaluation suggested that the aid produce this plan automatically. In addition, because the default emissions control plans for the SENSITIVITY command are the two "extreme" emissions control plans, plan ALL ON and plan INFO, it would be very convenient if the aid could construct this plan automatically.

Plan INFO may be implemented by following three rules for turning task group radars on or off. These rules are:

1. Those radars aboard the high value ship that are common to all ships in the task group are turned on. All other radars on the high value unit are turned off.

2. Those radars aboard lower value ships that are also aboard the high value ship are to be turned on.

3. Those radars aboard lower value ships that are not aboard the high value ship must be turned off.

The aid user can elicit plan INFO with the command EMCON, INFO.

## 3.2 THE EFFECT OF ADVERSARY ASSUMPTIONS ABOUT PROBABLE U.S. TACTICS ON INFERENCES OF THE IDENTITY OF TASK GROUP SHIPS

Orange assumptions about probable U.S. tactics can have a major impact on the interpretation of emissions observed from the task group and, therefore, can strongly impact Orange targeting and the resultant damage to the task group from a missile attack. Because it would be difficult to explain these information warfare tactics in general abstract terms, these sections will explain these tactics using an example.

### 3.2.1 A Scenario for Examining Information Warfare

The following scenario was previously used to train participants for the formal aid evaluation. Table 3-1 shows the radar order of battle.

If all task group radars are emitting, then an adversary who can detect, localize, and classify these radars by type, who knows that the four ships in Table 3-1 are in the operating area, and who knows their radar order of battle, will be able to deduce the locations of each of the ships. He could do so using the following reasoning. First, by observing that since only one of the four ships has an SPS-37, the SPS-37 emissions must be from the Gridley. Second, since of the remaining three ships only one

TABLE 3-1

RADAR ORDER OF BATTLE FOR ILLUSTRATIVE BATTLE GROUP

| | SPS-10 | SPS-30 | SPS-43 | SPS-52 | SPS-48 | SPS-37 |
|---|---|---|---|---|---|---|
| Kitty Hawk | x | x | x | x | | |
| Chicago | x | x | x | x | x | |
| Gridley | x | | x | | x | x |
| Vireo | x | | | | | |

has an SPS-48, the remaining SPS-48 source must be the Chicago. Third, since only one of the two remaining ships have radars other than the SPS-10, the remaining source of multiple emissions must be the high value ship, the Kitty Hawk. Finally, by a process of elimination, the source of the solitary SPS-10 must be the Vireo.

In this deductive process each of the inferences is "hard." A "hard" inference is a conclusion based only on observations and background information regarded to be certain. Such "hard" inferences may be defined as those inferences unambiguously concluded from observations rather than being dependent on guesses of likely adversary tactics, mission, and doctrine. With the EMCON plan ALL ON, the observer can identify all platforms unambiguously. He does not have to base his identifications on estimates about likely U.S. doctrine. In information warfare tactics, the "hard" information given away limits the opportunity to deceive an adversary. In this case, for example, the "hard" information conveyed by the emissions removes any possibility of deceiving an adversary by adopting unusual tactics.

In contrast to the "hard" inferences which limits opportunities for deception, there are other "soft" inferences that offer opportunities for deception. These "soft" inferences may be defined as adversary guesses based partly on observed signals and also on possible U.S. information warfare. The following discussion indicates how different U.S. tactics can lead to different adversary conclusions based on soft inferences, describes how an adversary who knows the general U.S. tactic in advance can tailor his inferences for such tactics, and finally discusses how the U.S. can force an adversary to hedge in all conclusions dependent on soft inferences.

### 3.2.2 "Normal" Bayesian Inference with a Deceptive Emissions Control Plan

In this discussion, the term "Normal Bayesian Inference" is the Bayesian inference which assumes equal a priori probabilities for every ship assignment consistent with the observed pattern of emissions. Against an adversary using "normal" Bayesian inference the most deceptive emissions control posture is plan INFO. In this plan the Chicago radiates the SPS-10, SPS-30, SPS-43, and SPS-52. The Gridley radiates the SPS-10 and SPS-43, and the Vireo and Kitty Hawk each radiate only the SPS-10. Figure 3-1 shows the source locations of each of the detected radiations and summarizes adversary information.

In this Bayesian inference, the adversary lists those assignments of ships to places that are consistent both with the observations and with the known ship radar order of battle. Table 3-2 lists the eight evidence-consistent assignments of ships to places.

Bayesian inferences always require a priori probabilities for each alternative. In the inferences employed for previous demonstrations of the Emissions Control Aid, it is assumed that all assignments of ships to places that are consistent with the evidence are equally probable. In the above list, The Kitty Hawk is assigned to location C in four of the eight evidence-consistent assignments, and to location A in only one of these assignments. Therefore, the assumption that each assignment is equally probable leads to an assessment that the probability that the Kitty Hawk is at point A is .125 while the probability that the Kitty Hawk is at point C is .5. If in plan INFO above the Kitty Hawk is actually at A, and if the adversary used the Bayesian inference indicated above, then the U.S. deception would succeed.

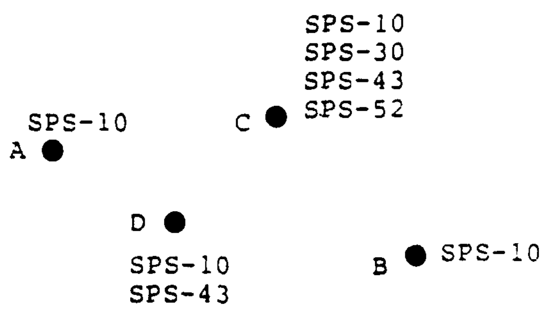



Figure 3-1. Orange Observations of Blue Task Group Radar Emissions

TABLE 3-2

ASSIGNMENTS OF SHIPS TO LOCATIONS CONSISTENT
WITH RADAR ORDER OF BATTLE IN TABLE 3-1
AND OBSERVATIONS IN FIGURE 3-1

| ASSIGNMENT | LOCATION | | | |
|---|---|---|---|---|
| | A | B | C | D |
| 1 | Kitty Hawk | Vireo | Chicago | Gridley |
| 2 | Vireo | Kitty Hawk | Chicago | Gridley |
| 3 | Vireo | Gridley | Kitty Hawk | Chicago |
| 4 | Gridley | Vireo | Kitty Hawk | Chicago |
| 5 | Vireo | Chicago | Kitty Hawk | Gridley |
| 6 | Chicago | Vireo | Kitty Hawk | Gridley |
| 7 | Vireo | Gridley | Chicago | Kitty Hawk |
| 8 | Gridley | Vireo | Chicago | Kitty Hawk |

This Bayesian inference may seem to be arbitrary and improbable. Nevertheless, similar conclusions might be reached using less formal and more "common-sense" reasoning. For example, an intelligence officer examining Fig. 3-1 may reach the same conclusions using the following reasoning:

1. The Vireo may be only at position "A" or "B" (hard inference). Therefore, the probability that the Vireo is at each of these positions is .5 (soft inference).

2. The Gridley cannot be at position C and therefore must be at A, B, or D. Since A or B is Vireo, Gridley can either be at A or D (if B is Vireo) or at B or D (if A is Vireo) (hard inference). Therefore, Gridley has a .5 chance of being D and a .5 chance of being either A or B. Overall, Gridley has a .5 chance of being at D, a .25 chance of being at A and a .25 chance of being at B (soft inferences).

3. Chicago and Kitty Hawk have radar orders of battle equally consistent with each of the radiation sources. Therefore, both could be assigned to any location with equal probability. However, at least one of the two must be at C since C cannot be either Vireo or Gridley (hard inference). Therefore, each has a .5 chance of being at C and a .5 chance of being at either A, B, or D. Since D has a .5 chance of being Gridley (from 2 above), and the other .5 probability is divided equally between Chicago and Kitty Hawk, D has a .25 chance of being each of these two ships. Further, if the Chicago is at C, then the Kitty Hawk has a .25 chance of being at A and a .25 chance of being at B. Since the Chicago could also be at A and B, however, the overall probabilities that the Kitty Hawk is at A or B are both .125 (soft inferences).

Although this reasoning gives the same probabilities as the Bayesian calculations with equal a priori weighting to each evidence-consistent assignment, in the informal reasoning outlined above the distinction between "hard" and "soft" inferences are clearer. There are two "hard" inferences--that Vireo is not at C or D, and that Gridley is not at D. All other inferences, including all the nonzero probability estimates, are soft. It is the uncertainties inherent in these soft estimates that the inferring side must hedge against, and that the other side may exploit with his information warfare tactics.

In reality, conclusions based on soft inferences reflect assumptions about Blue information warfare tactics. The following section illustrates an alternative inference process that could be used by an adversary who thought that Blue tactics would normally attempt to make the emissions from the high value unit inconspicuous. Orange conclusions about the probable identity of platforms of A, B, C, and D can depend heavily on these assumptions.

### 3.2.3 Ship Identification Inferences if Orange Were Certain that the Blue Tactic Is to "Hide" the High Value Ship

If Orange is positive that Blue would hide the high value unit by turning off all air search emitters on the high value ship, then Orange might infer the identities of the task group ships using the following reasoning:

1. The Kitty Hawk is not at C or D because these are sources of multiple emissions, an observation inconsistent with the assumption that the high value ship would have no emitting air search radars. Therefore, Kitty Hawk must be either at A or B (hard inference given certainty of tactic). Since Vireo, which carries no air search radars, can also be only at these two locations, (hard inference) the Kitty Hawk and Vireo together account for locations A and B. Therefore, Kitty Hawk and Vireo each are assigned

a .5 probability of being at location A or B (soft inference).

2. Since the Kitty Hawk or Vireo must be at A or B, the Gridley and Chicago may not be there and must accordingly be at C or D. Since Gridley has no SPS-30 or SPS-52, it cannot be at C. Therefore, Gridley is at D and Chicago is at C (hard inference if certainty of U.S. tactic).

The same conclusions may be reached using the Bayesian analysis with the a priori probabilities set to reflect the belief that the Blue tactic requires that all Kitty Hawk air search radars be silenced. Of the eight assignments of ships in Table 3-2 to places that are consistent with both the observations and also with the known radar orders of battle, only the first two are also consistent with the Orange tactical assumptions. The possible assignments of ships to places in this case are displayed in Table 3-3.

Assuming that each of these two assignments are a priori equally probable, then Orange assigns a .5 chance that the Kitty Hawk is at location A and a .5 chance that it is at B.

### 3.2.4 Heuristic Modification of Bayesian Inference for Orange Uncertainty about Blue Emissions Control Tactics

As these two previous sections illustrate, depending on Orange's assumptions about Blue's emissions control tactics, Orange could have concluded that the probability that the Kitty Hawk is at location A is .125 (equal weighting of all assignments consistent with the "hard" evidence), or is .5 (equal weighting of all assignments consistent both with "hard" evidence and also with the assumption that Blue is adopting a tactical plan which minimizes radiations from the carrier.) In fact, since the "hard" information does not preclude the Kitty Hawk from being at any of the four locations, Orange cannot rule out the possibility that the Kitty Hawk is at A, B, C, or D. If, however, Orange

TABLE 3-3

ASSIGNMENTS OF SHIPS TO PLACES CONSISTENT WITH RADAR ORDER OF BATTLE, OBSERVATIONS AND A U.S. TACTIC TO HIDE THE KITTY HAWK

| ASSIGNMENT | LOCATION | | | |
|---|---|---|---|---|
| | A | B | C | D |
| 1 | Kitty Hawk | Vireo | Chicago | Gridley |
| 2 | Vireo | Kitty Hawk | Chicago | Gridley |

wishes to make the best guess he can about the probability that the Kitty Hawk is at each of these places, then he may wish to use some sort of inference process to assign probabilities for the Kitty Hawk being at each of these places.

If Orange could accurately estimate the prior probabilities for each of the eight ship assignments, then he could better estimate the probability that the Kitty Hawk is at each of the locations. For example, if he felt that Blue is more likely to use an emissions control plan in which the high value ship radiations are minimized, he might weight the first two assignments more heavily than the other six. If he assumed that the first two assignments were twice as probable than the other six, he would compute that the Kitty Hawk has a .2 chance of being at A, B, and D, and a .4 chance of being at C.

In the absence of intelligence concerning the prior probabilities of assignments, such estimates may seem rather arbitrary. If Orange wishes to avoid such arbitrary judgments, then he may wish to use another method to assign such probabilities. The following section indicates how Orange could apply game theory to rationally derive estimates that the Kitty Hawk is at each of the locations.

### 3.2.5 Game Theory Formulation to Determine Ship Locations

In the game theory formulation of this information warfare problem, Orange does not need to assign a priori probabilities to the feasible assignments of ships to places. Instead, Orange derives such probabilities from an assumption that Blue will choose his information warfare tactics to minimize Orange's knowledge.

In game theory, each of the two sides adopt strategies, and the outcome of the game depends on the Orange-Blue strategy pair selected. In this case, the Blue strategies will be emissions control doctrines and the Orange strategies will be inference algorithms appropriate to each of the Blue strategies.

For the present example, Blue might consider the following four emissions control strategies; ALL ON, the maximum surveillance plan; INFO, the maximum deception plan when Orange assigns equal probabilities to each feasible assignment; INFO + KH, INFO with emitters on the high value unit radiating; and INVERSE INFO, the maximally deceptive plan assuming that Orange is anticipating deceptive tactics. This example will consider two Orange inference strategies, a NORMAL one which assumes equal a priori likelihoods of feasible assignments, and an INFO which assumes that Blue would adopt plan INFO. Table 3-4 is the outcome table for these strategies. For this discussion the outcome entries are the probabilities assigned by Orange to the Kitty Hawk being at location A, its true location. The reasoning illustrated here would also apply, of course, if the game table entries were some other outcome measure such as the calculated task group value surviving an Orange strike. In that case, however, the outcome table entries would change and the mix of strategies in the solution would differ from the present example.

With probability of correct HVU ID outcome measure, two of the Blue strategies bound two of the others. Since for both of Orange's strategies Blue's outcome for plans ALL ON and INFO + KH are inferior to the other two strategies, plans ALL ON and INFO + KH will not appear in the game solution. The solution for Blue will be a random combination of Blue's INFO and INVERSE INFO emissions control plans and for Orange a random combination of its NORMAL and INFO inference algorithms. At the solution point Blue will use a mixed strategy which causes it to be indifferent between Orange's two strategies, and Orange will use a mixed strategy which causes it to be indifferent between the two remaining Blue strategies. Solving this game gives a payoff, the probability that Orange will infer correctly that the Kitty Hawk

TABLE 3-4

INFORMATION WARFARE OUTCOME TABLE*

| | ORANGE STRATEGY | |
|---|---|---|
| BLUE PLANS | NORMAL | INFO |
| ALL ON | 1. | 1. |
| INFO | .125 | .5 |
| INFO+KH | .5 | .5 |
| INVERSE INFO | .5 | 0 |

---

*The outcomes are probabilities assigned by Orange to Kitty Hawk being at location A, its true location.

is at A, is .288. At the solution, Orange uses strategy NORMAL .57 of the time and strategy INFO the rest of the time and Blue uses plan INFO .57 of the time and plan INVERSE INFO the rest of the time.

Given this game result, it is possible to infer the "a priori" probabilities for the eight feasible ship assignments consistent with the outcome strategies. When Orange uses the NORMAL strategy, he weights each of the assignments equally. When Orange uses the INFO strategy, he gives the final six assignments zero weight. Therefore, he will achieve the game solution if in his Bayesian computations he gives the first two assignments weights of .288 (.125 x .57 + .5 x .43) and the last six assignments weights of .072 (.125 x .57 + 0. x .43).

In the new EWAR algorithm for information warfare, the user selects a parameter which calculates relative a priori weights for ship assignments according to how many times a pattern of emissions conflicts with what would be expected from an adversary using a plan INFO. By selecting this parameter appropriately, the aid user can duplicate the information warfare outcome. At present, however, the user cannot command the aid to compute the game theory solution automatically. Rather, he can use the new information algorithms to generate a table such as Table 3-4. From this table, he could compute the information warfare scenario, and then compute the appropriate information warfare parameter. An efficient way for the aid to compute such a parameter automatically would be an important aid enhancement. Although finding such a procedure could be a significant research effort, it is likely that such research would succeed.

## 4.0 SUMMARY: DEVELOPMENT OF AN EMISSIONS CONTROL DECISION AID

Under the operational decision aiding program, projects were developed over several years so that different participants could benefit from mutual activities and experiences. DSA has benefited considerably from this interaction. Continuing this dialogue, this final summary will discuss conclusions about decision aid design attained from DSA's multi-year development experiences.

### 4.1 SELECTION OF DECISION AIDING SUBJECT

During the past several years DSA has briefed large numbers of Naval officers on the Emissions Control Decision Aid. Many of these officers were enthusiastic about the aid, believing it had considerable potential for supporting tactical command decision requirements. Probably the most important reason for these endorsements was that the decision aid focused on a problem well chosen for decision aiding.

Although there are many criteria for identifying what operations would benefit most from decision aiding, three proved particularly important in the choice of an aid for emissions control. First, the problem must be important enough to warrant the expense of developing an aid. The consequences of selecting one alternative rather than another must be significant. Second, the decision must be difficult enough to benefit from aiding. If the proper decision choice is usually obvious, then an aid will not improve the quality of the decision. Third, the physical factors that would influence the choice of a decision alternative must be well enough understood to be credibly modeled.

Emissions control satisfies these three requirements. First, a successful emissions control plan which denies an adversary knowledge of a task group's whereabouts or which denies the information needed to successfully target the task group high value unit, may assure the success of the naval mission. On the other hand, silencing emissions needed to obtain vital information can seriously reduce task group effectiveness. The aid, which balances information denied to an adversary by silencing emitters with the information obtained by radiating emitters, can improve the quality of selected emissions control postures.

Second, because it is difficult to calculate either the information to be gained or the information lost manually, the problem difficulty warrants aid development. Finally, for specified scenario assumptions, both the information gained and denied can be computed from known physical laws and simulations of inferences.

## 4.2 DESIGN OF DECISION AID DISPLAYS

Although there are many guidelines for designing effective decision aid displays, none of the displays initially developed according to such rules proved to be satisfactory. Rather, satisfactory displays evolved as DSA responded to the reactions of briefed Naval officers and scientists. On occasion someone would suggest a particular new design to replace an older display, or would suggest an additional needed display. More frequently, however, displays needing improvement were identified when they confused audiences. Sometimes in such cases the designer of the display, convinced of the display's merit and sure that users would eventually grow to understand it, would persist in retaining the display. Such persistence always proved fruitless. Thus, it became apparent that no matter how fondly a display developer may feel toward his display, a perplexed or confused reaction from the audience mandates a display design change.

The Emissions Control Decision Aid has a hierarchy of displays. Highest in the hierarchy are displays giving such fundamental operational consequences of an emissions control posture as task group surviving a missile attack. These displays provided the information most relevant to command decisions. However, they were also the most dependent on possibly inappropriate internal aid models and scenario assumptions. Supplementing such operationally linked displays were others, like the one showing maximum radar detection ranges, which are less closely related to mission success but also less dependent on scenario assumptions. It was felt that users would rely on these displays to calibrate and check the output of the more mission-related displays. Although at sea such displays might be used to check aid calculations in which the user lacked confidence, participants in the formal test evaluation relied almost entirely on the displays that were most mission related. They rarely, if ever, used the possibly more reliable but less mission related displays.

## 4.3 NEW USER INTERFACE

The tendency for the test participants to rely almost exclusively on highly aggregated measures of effectiveness in evaluating an emissions control plan and to largely ignore other more fundamental but less mission-oriented displays motivated the development of the new user interface described in this report. Since this interface had not been developed at the time of the formal aid evaluation, there is no formal evaluation of how well it would work. Nevertheless, the development of the interface was an important step in converting the aid from a research and development project to one useful in practical tactical command situations. The work on the interface clarified the context in which the aid would be used--both in terms of its mission contributions, and also in terms of its operational and system interfaces.

## 4.4 THE FUTURE OF THE EMISSIONS CONTROL DECISION AID

The decision aid has been developed to a point where the potential value of the kinds of information it can provide can be assessed. If such information is judged to be sufficiently important to Navy operations, then it may be practical to begin converting the aid to an operational sytem.

The short-term goal in this conversion would be the development of a demonstration system which could be evaluated as part of a realistic tactical wargame, preferably using an on-shore simulation such as the Warfare Environment Simulation (WES). In this environment Naval officers would have the option to use the aid as they formulate their tactical plans. If experience proves that using the aid improves combat performance, then a prototype of the aid might be developed for at-sea evaluation.

The decision aid, after modification for the shore-based evaluation, would continue to emphasize its most important design feature. Specifically, it would focus on providing estimates of the useful information that could be deduced from a set of emitting radars and the tactical early warning that could be provided by such radars. In addition, it would continue to relate these estimates to a meaningful operational measure of effectiveness, such as expected task group damage from an adversary missile attack.

The aid would be modified, however, so that it integrates easily with the other shipboard systems. At present the aid has simple models for adversary signal detection capability, for task group air defense, for adversary targeting inferences, and for radar performance. In the shore-based evaluation, however, the aid modules for such computations would be replaced whenever possible with inputs from other systems designed to accomplish these functions.

After such conversion the Navy would have an opportunity to evaluate one of the first of a new generation of decision aids--an aid designed for information warfare which estimates an adversary's estimate of the tactical situation, which effectively integrates the output from other shipboard systems, and which relates such outputs to mission effectiveness.

APPENDIX A

# EMISSIONS CONTROL INTERVIEWS AND THE CONSTRUCTION OF AN INFLUENCE DIAGRAM FOR INFORMATION WARFARE

Information obtained in the interviews described here supports the development of a new aid interface which would help the user relate aid inputs, functions, and outputs to specified command objectives, to operational constraints, and to the existing tactical environment. The information desired, therefore, includes identification of all common emissions control objectives and an understanding of those factors believed by Naval officers to be most important when selecting a plan to meet these objectives in common tactical situations.

This section discusses the use of influence diagrams to structure the interview, reviews the information obtained by the interviews, and summarizes the interview results using influence diagrams. The first three subsections describe interview preparations. They review the assumptions in the aid prior to the interviews, summarize the general interviewing format developed with SRI, and describe the format refinement for these specific project purposes. The last two subsections discuss the interviews themselves. DSA conducted two sets of interviews. The first set concerned emissions control in general. Several months later DSA conducted a refinement interview which focused on emissions control in information warfare.

## A.1 DEVELOPMENT OF INTERVIEWING TECHNIQUE USING INFLUENCE DIAGRAMS

DSA adapted the decision aiding methodology used by the SRI International's Decision Analysis Group for these interviews. This section outlines the methodology agreed upon during initial consultations with SRI. The methodology was directed toward interviews which would clarify the objectives of emissions control decisions, elicit the various decision alternatives, and clarify the critical factors influencing an outcome. Section A.1.1 discusses the interviewing technique for identifying objectives and decision alternatives. Section A.1.2 then discusses interviewing techniques for identifying and analyzing critical factors. Whether directed toward identifying objectives or clarifying critical factors, the first questions are general ones designed to identify the most important items while the later questions refine the information provided earlier and pursue promising areas in greater detail.

### A.1.1 Identification of Decision Objectives and Alternatives

The interview begins with a discussion of mission objectives and explores how emissions control decisions can impact mission success. Usually it is difficult to predict how a decision might affect overall mission success. Therefore, the discussion focuses on identifying more computable subobjectives appropriate to the specific decision alternatives being considered. In the emissions control problem, for example, the overall mission may be to provide a show of force while the more computable subobjective of an emissions control posture would be to support this mission by increasing task group security. The more easily measured objectives subordinate to ensuring task group security might be to minimize information available to an adversary, to maintain surveillance for a possible surprise attack, and to monitor adversary movements.

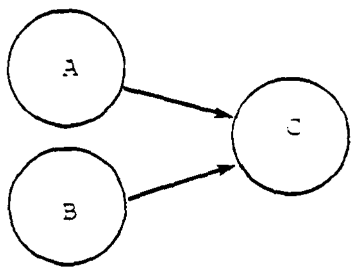
After the rather specific objectives for emissions control are identified, the interviewer attempts to identify outcome measures which reflect these objectives. The interviewer first asks the interviewed person for a list of possible outcome measures. Once a preliminary list is compiled, the interviewer attempts to refine it. The interviewee is asked to add items that he had previously overlooked, some of which may be suggested by the interviewer at this time. The interviewee is then asked to select those items that are most important and should be retained for further consideration. A preliminary list might have included the length of time the carrier is "down," whether or not repairs must be made, and the length of time various support ships would be unavailable. On further consideration, the interviewee might add to the list the number of injuries and the number of deaths that might occur from a surprise missile attack. Those outcome measures later identified as most important and which should be retained for further consideration could be the length of time the carrier is down and the expected damage to other task group support ships.

This same general procedure is applied to enumerating and refining the decision alternatives. Several alternatives are mentioned; this list is then refined. For emissions control the initial list might include an emissions control posture of complete silence, one with no emissions restrictions, and another in which signals unique to the high valued unit are silenced.

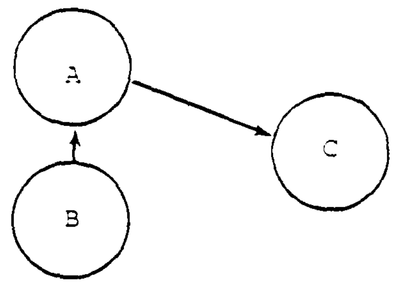
### A.1.2 Identification of Critical Factors and the Construction of Influence Diagrams

Critical factors are uncertainties which could influence which alternative is preferred. Influence diagrams provide a convenient way for identifying these factors, and for showing their relationship to the decision alternatives, to the decision objectives, and to each other. The following discussion, which illustrates how an influence diagram may be developed during an interview, should explain how influence diagrams can represent the relationship between alternatives, outcomes, and critical uncertainties (see Fig. A-1).

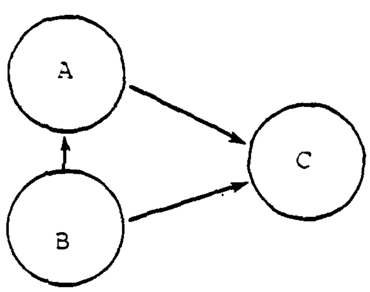
The influence diagrams were constructed by asking questions which first outline a structure, then elaborate it, and finally refine it. The interview sequence for identifying and understanding the critical factors is illustrated below with the factors A, B, and C. Suppose that it had been stated previously that factors A and B affect C, and that both factors A and B are important enough to be retained for further consideration. The tentative relationship between A, B, and C is indicated in



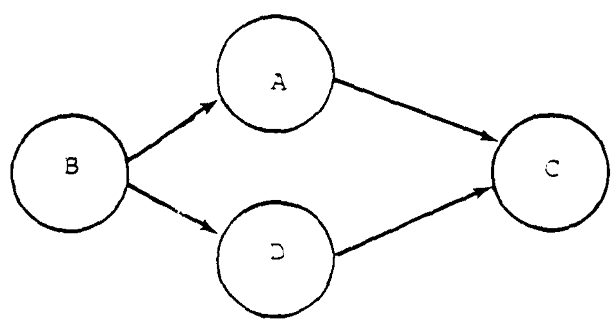

a. Factors A and B Influence Factor C




b. Factors A and B Influence Factor C, but the Effect from Factor B is Mediated Entirely Through Factor A




c. Factors A and B Influence Factor C; Factor B Also Influences Factor A but has in Addition a Direct Effect on Factor C




d. Factor B Affects Factor C in Two Independent Ways; Through Factor A and Also Through New Factor D

Figure A-1. Illustration of Development of an Influence Diagram During Interview

AD-A105 504 DECISION-SCIENCE APPLICATIONS INC ARLINGTON VA F/G 17/2
A PROTOTYPE INTERFACE TO ADAPT DECISION AIDS TO USER SCENARIO A--ETC(U)
JUL 81 D F NOBLE, G E PUGH N00014-77-C-0322
UNCLASSIFIED DSA-335 NL

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Fig. A-1a. The arrows in this figure point from the influencing factor to the influenced factor.

The interviewer begins to clarify the relationship between A, B, and C by asking if A or B influence one another. If not, then Fig. A-1a correctly represents the relationship between A, B, and C. If, on the other hand, B influences A, then the interviewer asks further questions to determine the nature of this influence.

First, there is a possibility that the influence of B on C is mediated entirely through A. To check this, the interviewer asks if fixing the value of A removes the influence of B on C. If so, then factor B affects C only through A, and the relationships in Fig. A-1a are revised to those in Fig. A-1b.

If, however, the subject indicates that both A and B must be known to determine C, then the more complex diagram of Fig. A-1c expresses the appropriate relationship.

Sometimes factor B influences A and C by entirely different mechanisms. To identify these mechanisms the interviewer might ask for an intermediate variable between B and C which is affected by B but which does not affect A. If such a variable can be found, then the influence diagram of Fig. A-1c can be expanded to that of Fig. A-1d. Alternatively, he might find an intermediate between B and A which explains the differing mechanisms.

The following examples from a hypothetical interview concerning emissions control may clarify the previous discussion. Suppose that the subject had mentioned that the number of hits, weapon yield, and damage per hit each had major effects on damage sustained by a missile attack. In the preliminary influence diagram each of these factors are shown directly influencing carrier damage (Fig. A-2). In the follow-up questions however, the subject states that the damage per hit depends on weapon yield and that, if one knows damage per hit, then knowing weapon yield does not improve the ability to estimate carrier damage. Therefore, the improved influence diagram of Fig. A-3 would indicate damage per hit and number of hits as the two direct influences on carrier damage, with weapon yield as a secondary influence acting through damage per hit.

The interviewer now focuses on the factor "number of hits." He might be told that two factors, "emissions control posture, (EMCON plan)" and "number of missiles penetrating defense" affect "number of hits" and that "EMCON plan" also influences "number of missiles penetrating." Figure A-4 summarizes this relationship between "number of hits," "number of missiles penetrating," and "EMCON plan." Because the interviewee states that "number of hits" would depend on "EMCON plan" even if the number of missiles penetrating were fixed, these relationships are examined further.

The interviewer now seeks to determine the mechanisms by which "EMCON plan" affects "number of hits" and "number of missiles penetrating," searching in particular for independent mechanisms. The interviewer asks for a possible intermediate factor between "EMCON plan" and the direct link to "number of hits." The factor "missile accuracy" is suggested as this intermediate factor. It is explained that emissions control can reduce effective missile accuracy by silencing emissions with frequencies used for missile homing. The interviewer next probes the relationship between "EMCON plan" and "number of missiles penetrating the defense." The factor "warning time for missile attack" is identified to be an intermediate variable between "EMCON plan" and "number of missiles penetrating defense." Increased warning time of a missile attack decreases the number of missiles penetrating because it increases the range at which missiles are detected, thereby increasing interception opportunities.

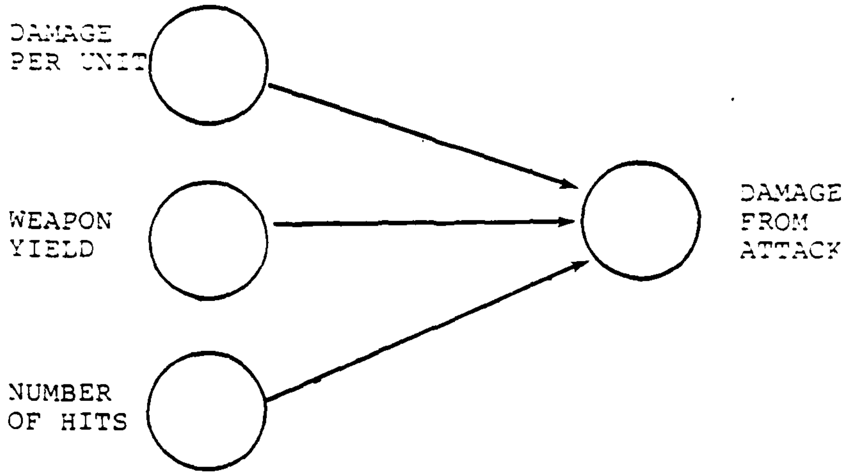



Figure A-2. Preliminary Influence Diagram. Number of hits, weapon yield, and damage per hit affects damage from missile attack.

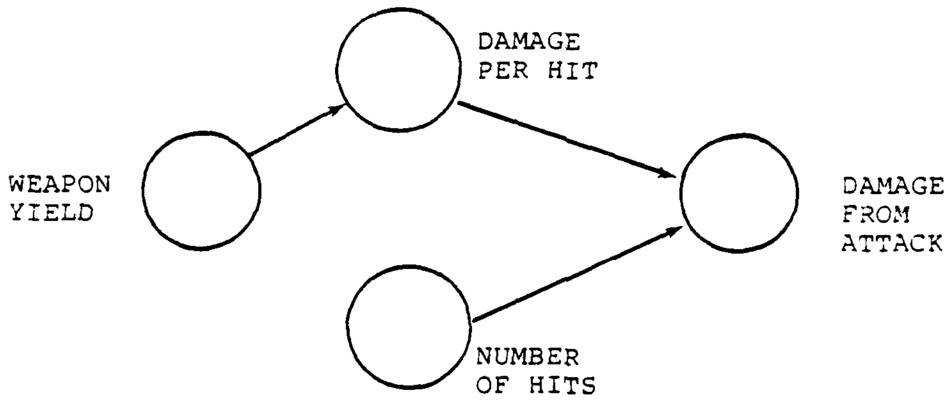



Figure A-3. Refined Influence Diagram. Weapon yield affects damage from attack exclusively through its effect on damage per hit.

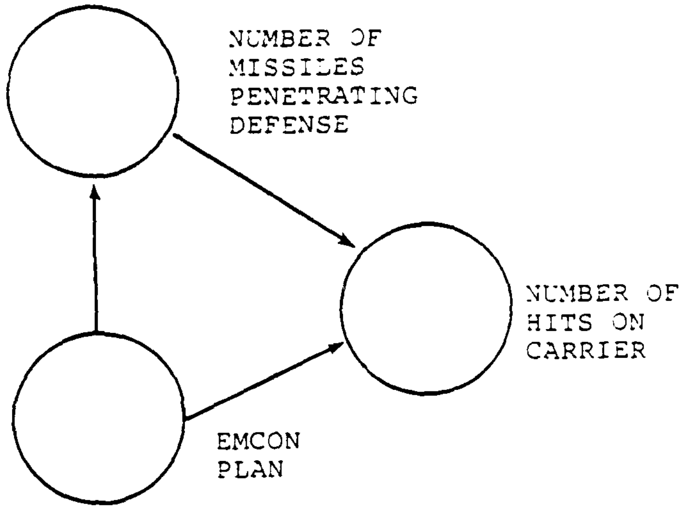



Figure A-4. "EMCON Plan" Affects "Number of Hits" Directly, and Also Indirectly Through a Number of Missiles Penetrating Defense

Thus, these follow-up questions have revealed that emissions control affects "number of hits" through two entirely different mechanisms--by providing missile terminal homing frequencies and by influencing the task group ability to detect missile attacks quickly. Figure A-5 shows the refined influence diagram showing these relationships.

In this illustrative interview, the interviewee did not mention another important mechanism by which emissions control affects "number of hits on carrier," the number of missiles directed against the carrier. Task group emissions provide clues to the identity of task group platforms, which permit an attacker to concentrate his attack more effectively on the high valued unit. A skillful interviewer who continued to probe for additional mechanisms would likely uncover this factor either later in this interview or in a subsequent one.

## A.2 FINAL PREPARATION FOR INTERVIEWS--CONSULTATIONS WITH OPNAV AND NAVELEX NAVAL OFFICERS

Before beginning the interviews, DSA discussed the proposed procedure with several Naval officers in OPNAV (OP-944) and NAVELEX (PME-107).

These discussions with OPNAV and NAVELEX improved the interview approach by suggesting a question order and specific wordings that would seem natural to the interview subjects, but which maintained the general interviewing sequence agreed upon with SRI. The interviewing sequence resulting from these consultations begins with two orienting questions that review standard operational situations requiring emissions control, and then advances to other questions seeking the more detailed information required for this project. The first question reviews current doctrine. The second two focus on objectives. Question four discusses possible alternatives to standard plans. The last three questions discuss important influences on emissions control choice. The specific questions and

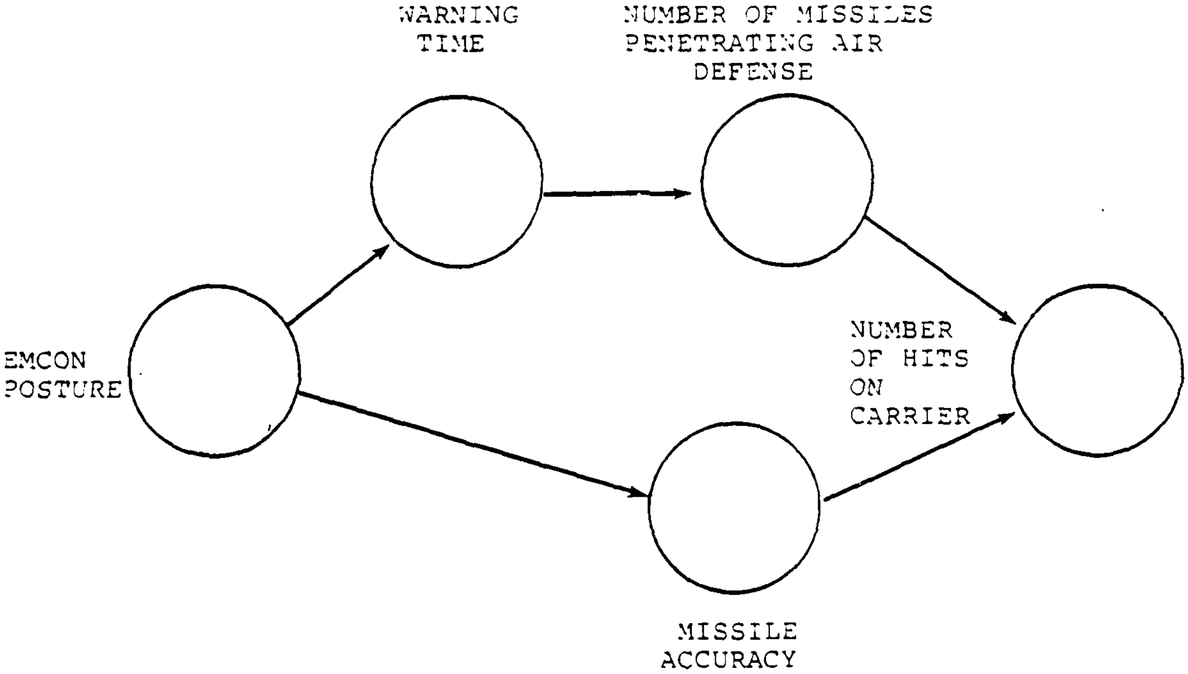



Figure A-5. Influence Diagram Indicating that Emissions Control Affects Number of Hits in Two Different Ways--by Providing Homing Frequencies and by Affecting Task Group Early Warning Time of Missile Attack representative answers are listed in Table A-1. These DSA-supplied answers were developed prior to the interviews. They were intended to improve communications with the OPNAV and NAVELEX advisors and are not intended to represent either the answers that DSA thought most probable, or that DSA actually obtained in the subsequent interviews.

## A.3 FIRST SET OF INTERVIEWS

During the first set of interviews DSA and SPI interviewed Naval officers at the Naval Air Station, North Island, San Diego.

The interviews with these officers followed a format similar to that outlined above, with digressions and elaborations that seemed promising during the conversations. Each of the interviews lasted between 30 minutes and an hour.

### A.3.1 Summary of Interview Content

These interviews were devised to focus on emissions control problems as experienced by the interviewees. The subjects were not told about the decision aid, nor were they told that the purpose of the interviews was to further development of a decision aid/user interface.

The information provided by these officers reflected their divergent specialized interests. There was very little information duplicated in the interviews and no conflicting opinions from the interviewees. Because the information obtained during the interviews reflected different specialized interests, the data proved difficult to integrate.

The interviewees identified three basic emissions control scenarios--open ocean transit, during missile attack, and information warfare. Table A-2 lists several objectives identified as important in information warfare, and Table A-3 organizes the more detailed information obtained from these interviews. This table reflects a significantly broader view of

TABLE A-1

DSA-SUGGESTED INTERVIEW QUESTIONS
WITH ILLUSTRATIVE DSA-SUPPLIED ANSWERS

1. There exists today standard situations requiring emissions control. What are these situations?

   a. Sea lane protection.

   b. Power projection: low threat.

   c. Power projection: high threat.

2. For each situation there exists standard plans. What is the principal objective of each standard plan?

   Plans and objectives appropriate to the high threat power projection scenario are:

   a. All off: minimize effectiveness of enemy passive surveillance.

   b. All on: maximize task force surveillance capability.

   c. Deceptive EMCON to decoy targeting from the high value unit. This plan would retain some surveillance capability, but deny information needed to identify the high valued unit.

3. In addition, in each situation adoption of an EMCON plan means sacrificing certain other objectives. What are these other conflicting objectives?

   With the deceptive plan, the conflicting objectives are:

   a. Emissions present give away task group presence and permit some passive surveillance by potential attackers.

   b. Emissions turned off degrade own force communication and surveillance capabilities.

4. Are other EMCON plans possible which do not seriously degrade the primary objective but significantly improve performance on other objectives?

   a. Tailor standard deceptive plan for enemy surveillance resources, attack capabilities, and assumed enemy level of intelligence.

   b. Use blip enhancer to deny attacker ship size information from active radar return. Position low valued ships within the formation at stations appropriate for the high valued unit.

5. What factors affect most critically the choice of a good trade-off plan?

For high threat power projection mission:

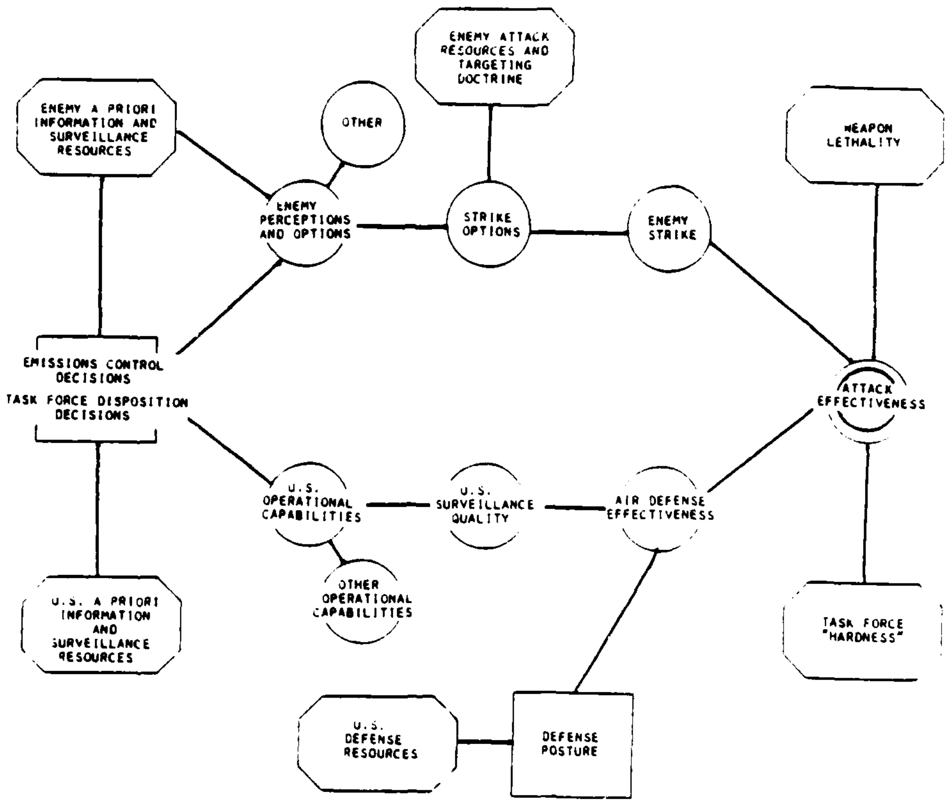
a. Enemy capability to evaluate information, targeting doctrine, attack resources.

b. Own surveillance and defense resources.

6. How would one assess how each of these factors could influence each of the conflicting objectives? What other information is required to make such an assessment?

The relationship between different factors and their effect on task force survivability are diagrammed in the following chart.

| | |
|---|---|
| (Square) | U.S. posture decision |
| (Octagon) | Factors critical to emissions posture decision |
| (Circle) | Outcome dependent on critical factors |
| (Double circle) | Effectiveness measure |



7. How would you describe the kinds and values of planning factors needed to compute the consequences of EMCON plan choice on each important objective?

Description of enemy surveillance capability:

Suspected enemy surveillance platforms, distance and bearing from CV and ESM capability.

| | | | | |
|---|---|---|---|---|
| 1. | BADGER | 300 nmi | $90^\circ$ | ESM type 3 |
| 2. | SATELLITE CLASS A | | | ESM type 1 |
| 3. | SUBMARINE CLASS C | 40 nmi | $270^\circ$ | ESM type 6 |
| 4. | DESTROYER CLASS B | 80 nmi | $75^\circ$ | ESM type 10 |
| 5. | DESTROYER CLASS D | 110 nmi | $95^\circ$ | ESM type 10 |

TABLE A-2

EMISSIONS CONTROL OBJECTIVES IN INFORMATION WARFARE*

A. Improve own force performance

1. Maintain intelligence and coordination between own forces.

2. Determine enemy threat and surveillance resources.

3. Determine enemy maneuvers characteristic of a mission.

4. Early warning of enemy attack.

B. Degrade enemy performance

1. Deny presence, task force size information.

2. Deny knowledge of formation indicative of specific missions.

3. Deny specific targeting information.

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*This list is compiled from answers volunteered during the first set of interviews.

TABLE A-3

SUMMARY OF INFORMATION ACQUIRED
DURING THE FIRST SET OF INTERVIEWS

INFORMATION WARFARE

I. U.S. information independent of U.S. EMCON posture--no information revealed.

   A. Non-task-group sources.

      1. P-3 shore-based.
      2. External message traffic.

   B. Task group - submarine.

   C. Passive systems focused on enemy.

      1. Communication monitoring.
      2. ESM directed against enemy active systems.

         a. Ducting - atmospheric profile.
         b. Clutter on screen from all sources.

      3. Passive on passive systems.

         a. IR.

II. U.S. information independent of U.S. EMCON posture. Gives away presence of carrier only. Free if carrier presence already known.

   A. E-2 radar.

   B. S-3.

III. U.S. information to be gained by own resources.

   A. Resources.

      1. Shipboard radars.
      2. Approach radars.
      3. HFDF.

   B. Coordination of own resources.

      1. Communication. UHF limited to line-of-sight. Requires close formation.
      2. NTDS.
      3. Mutual interference of search radars.

IV. Information available to threat independent of U.S. EMCON plan.

   A. Visual.

      1. Cloud cover - density.

B. Information difficult to know.

1. Material condition of radars.

V. Threat capability to gather information.

A. Threat surveillance resources.

1. Aircraft.
2. Submarine.

B. ESM capability.

1. Atmospheric profile.

C. U.S. countermeasures.

1. Blip enhance.
2. Deception with vans.

VI. Value of information.

A. Enemy attack effectiveness.

1. Threat resources.
   a. Submarine threat.
2. Tactic effectiveness.
   a. Attacker can tailor flight to atmospheric conditions.

B. U.S. defense effectiveness.

1. Against air threat.
   a. Defense in depth.
   b. Mutual defense.
2. Submarine threat defense.

## OCEAN TRANSIT

I. Optimum transit route.

II. EMCON doctrine.

A. Operate commercial radars only.

## EMCON DURING AIR ATTACK

I. Enemy attack effectiveness.

A. Threat resources.

1. Anti-radiation missiles.

II. U.S. defense.

A. Resources.

1. Fire control radars.

B. Posture.

1. EA6B can saturate screen.
2. Open formation--avoids interference of radars and screen clutter.

emissions control requirements than is represented by the aid. The context for emissions control was broadened from emissions control for task force defense to information warfare in general. Of the seven objectives for emissions control mentioned by these officers, only the objectives of providing early warning of enemy attack and of denying specific targeting information are addressed by the decision aid.

The kinds of plans and the criteria for evaluating emissions control plans differ considerably for the three basic scenario types. In open ocean transit the primary objective is to avoid being detected. In this scenario, emissions control plans frequently emphasize silence. In the information warfare scenario, the task group has been detected. Both U.S. and adversary forces are attempting to gain an information advantage in pre-engagement jockeying. The third context for emissions control is during an air attack. In this situation the adversary missiles have been targeted, and emissions control concerns silencing emissions exploitable for missile terminal homing.

Because the decision aid supports emissions control planning only in the information warfare scenario, the interview questions focused on emissions control for information warfare. Even in this area the aid did not consider most of the factors thought to be important during the interviews. For example, the aid assumes that all information acquired by the task group commander derives from tactical sensors. Long-range surveillance and intelligence sources are not modeled. In the interviews long-range sensors are identified as extremely important sources of information. In the aid adversary information needed for targeting is acquired from radars and ESM, and U.S. warning of an attack is provided solely by task group radars.

A.3.2 Information Warfare Influence Diagram

Figure A-6 is the information warfare influence diagram constructed after the first set of interviews. The two large

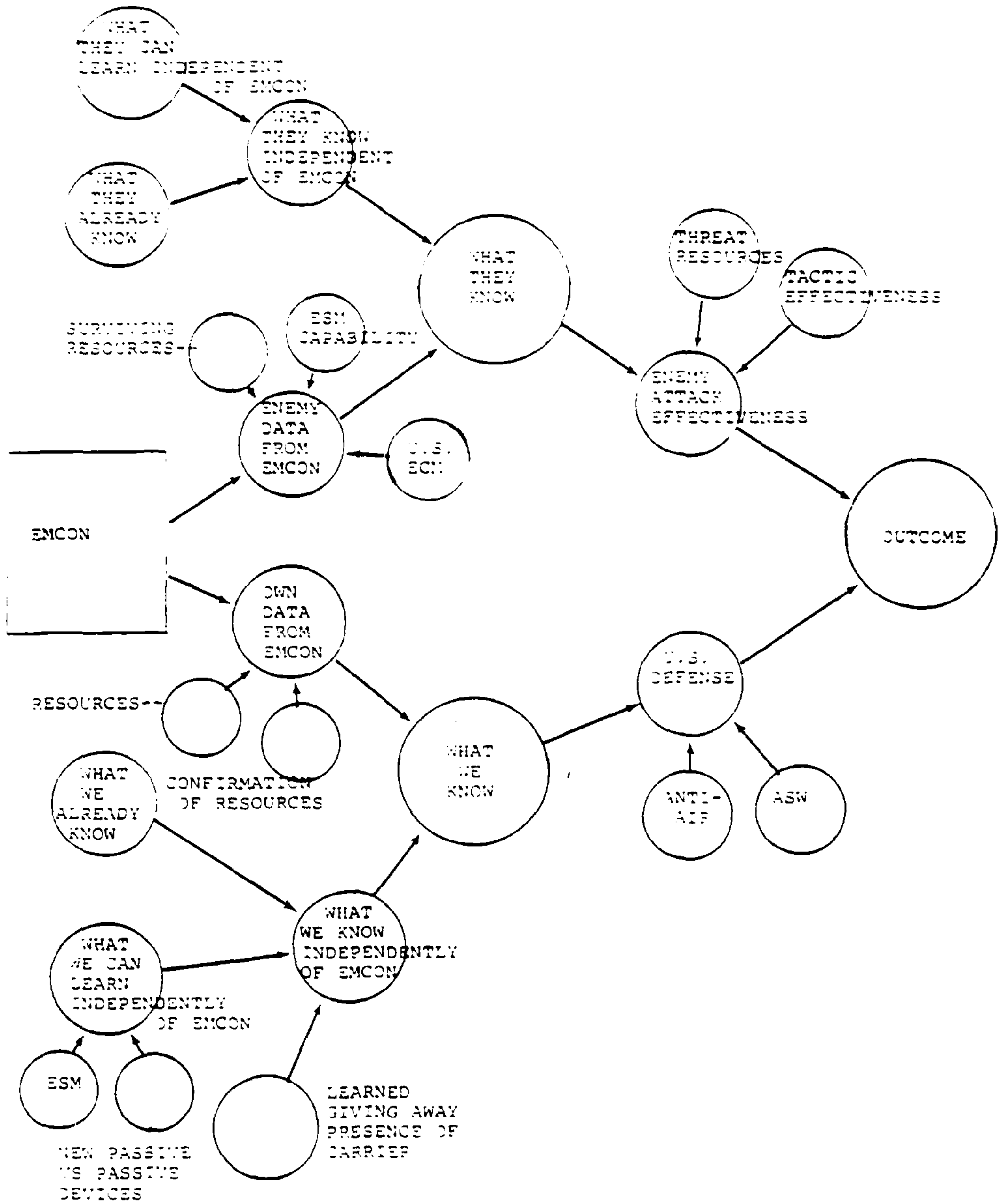


Figure A-6. Influence Diagram Summarizing Results From First Set of Interviews circles indicating adversary and friendly information are central to information warfare. In this diagram, drawn to highlight emissions control, all information sources that influence the overall Blue or Orange information states are classified by whether they depend on the emissions control posture or whether they are obtained independent of this posture.

During these interviews, one Naval officer succinctly summarized what information would be most useful to a planner making information warfare decisions. In his opinion, the most important information needed to evaluate the consequences of an emissions control plan are, first, the information already available to an adversary and second, the chance that an event will occur that the task group must know about. This opinion strongly affected the design of this influence diagram.

### A.3.3 Overview of Benefits from First Round of Interviews

These first series of interviews were extremely important to the development of the decision aid interface. They pointed out that emissions control is only one part of information warfare, and that the decision aid is an information warfare tool. They identified many previously overlooked factors important in information warfare, and indicated which of these would be most useful to include in the aid. Perhaps most important, the interviews indicated how the aid could serve to integrate the diverse factors affecting information warfare.

These interviews also suggested that the aid could help relate the output from other Navy $C^3$ systems to mission objectives. For example, one of the Naval officers being interviewed observed that many of the factors important in predicting the likely effectiveness of U.S. search radars were modeled in the Integrated Refractive Effects Prediction System (IREPS) developed at NOSC and currently being evaluated aboard the Kitty Hawk. This system models the environmental effects on radar detection capability in considerably more detail than in the aid itself. Its output is a detection range of an individual radar against a threat with a given velocity, altitude, and cross section. Because the aid combines the outputs from individual radars to display an overall surveillance capability for the entire set of active search radars, the aid could accept as inputs the output of IREPS. The aid could then process these IREPS outputs to compute the radar coverage from the entire set of task group radars and could estimate the implications of this coverage to mission objectives.

## A.4 THE FOLLOW-UP REFINING INTERVIEW

Several months after the first set of interviews, and after the information from those interviews had been assessed, DSA had the opportunity to interview the electronics warfare officer for a carrier group. As a member of the carrier group commander's staff, the task group electronics warfare officer is responsible for recommending the overall emissions control posture for a task group. Since he is concerned with the security of the entire task group, his evaluations of emissions control postures would include the kinds of factors that the aid considers. His responsibilities contrast markedly with those of the ship electronics warfare officer, who is concerned primarily with the operations of one ship rather than with overall task group coordination.

### A.4.1 Structure of the Follow-up Interview

Unlike the earlier interviews that were not restricted to a single class of emissions control scenario, this interview focused exclusively on emissions control in information warfare. The interview structure itself was significantly altered. Rather than asking the series of questions suggested during the preparations to the first interview, this interview sought comments and corrections to the influence diagram developed after the first set of interviews.

Figure A-7 displays the sequence of influence diagrams presented at the start of the interview. Each succeeding diagram contains more detail than the preceding one, augmenting its predecessor either by indicating where additional information would be added or by the content of this additional information. Although the interviewee was invited to comment on each of these diagrams, he corrected only the final most complete diagram. By the time the final diagram was shown, he had an excellent understanding of how DSA viewed emissions control for information warfare and could present his own views efficiently by suggesting changes to the DSA diagram.

A.4.2 Final Influence Diagram for Information Warfare

Figures A-8a-d are the new influence diagrams that integrate the information obtained in the final interview with the information obtained earlier. More information was obtained in the interviews than is shown in these diagrams, but many of these details are not included because they are classified.

Unlike the preliminary diagram, this one emphasizes the symmetry in information warfare. Both Blue and Orange are choosing information warfare tactics, including emissions control. Both are concerned with acquiring maximum information about the adversary while conveying minimum information about itself. Therefore, this diagram emphasizes that Orange emissions can affect the information states and outcomes as much as can Blue emissions. Because the Blue emissions posture is a decision alternative for Blue, they are represented by a box. Since in Blue's perspective the Orange emissions posture is a Blue planning uncertainty, this posture is represented by a circle.

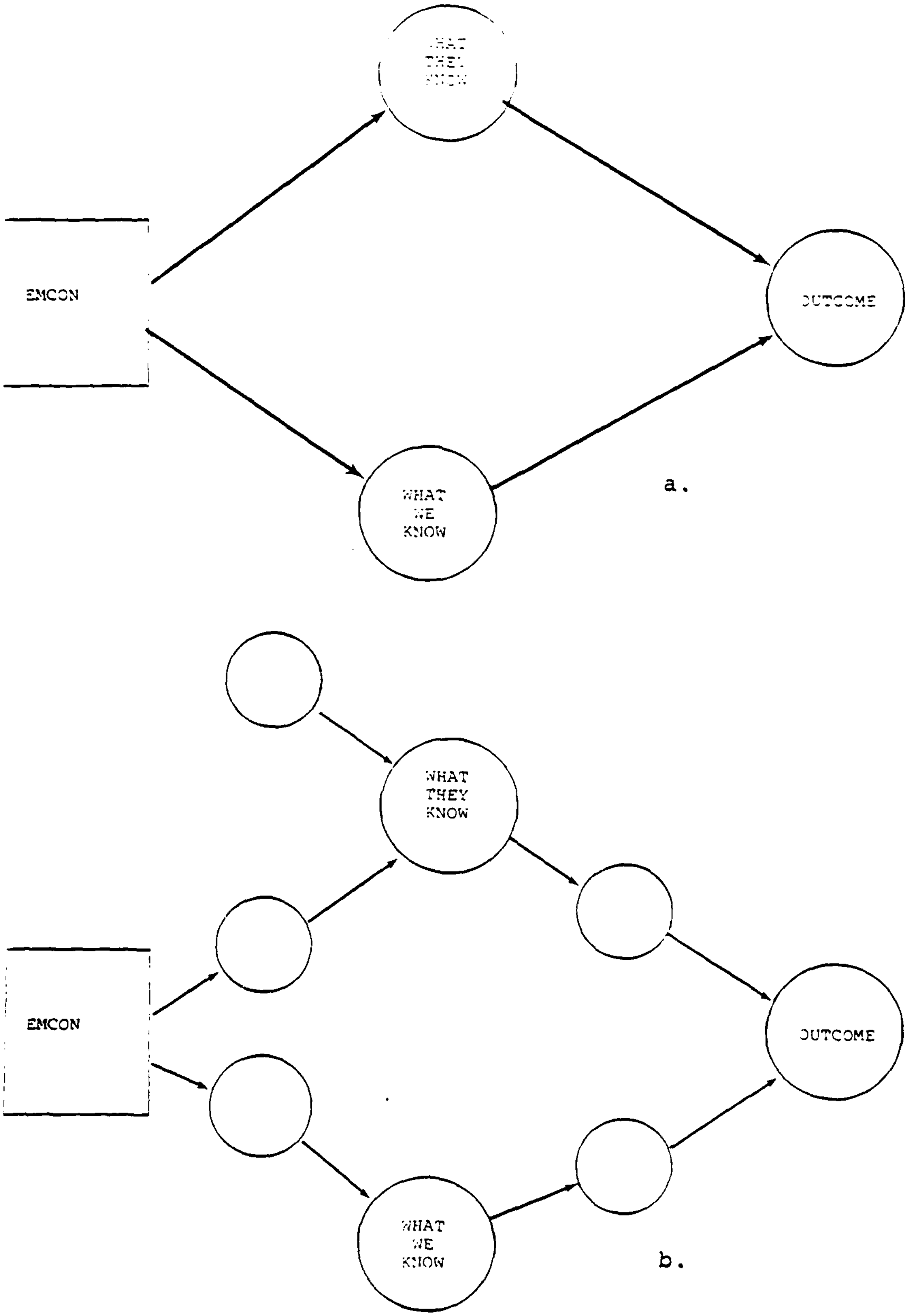


Figure A-7. Use of Influence Diagrams in Final Interview. These diagrams were presented sequentially to communicate DSA view of emissions control in information warfare.

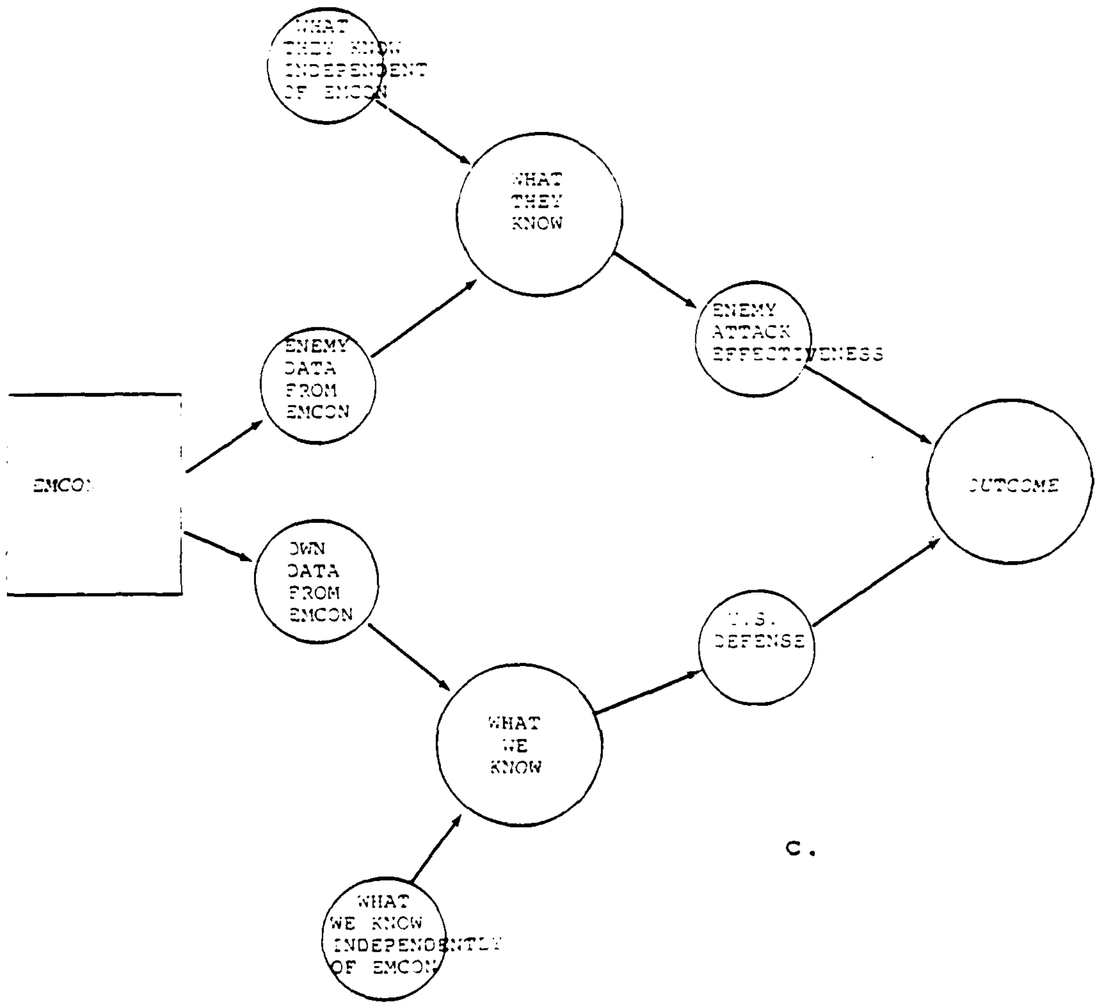


Figure A-7. Use of Influence Diagrams to Communicate to Final Interviewee (Cont'd)

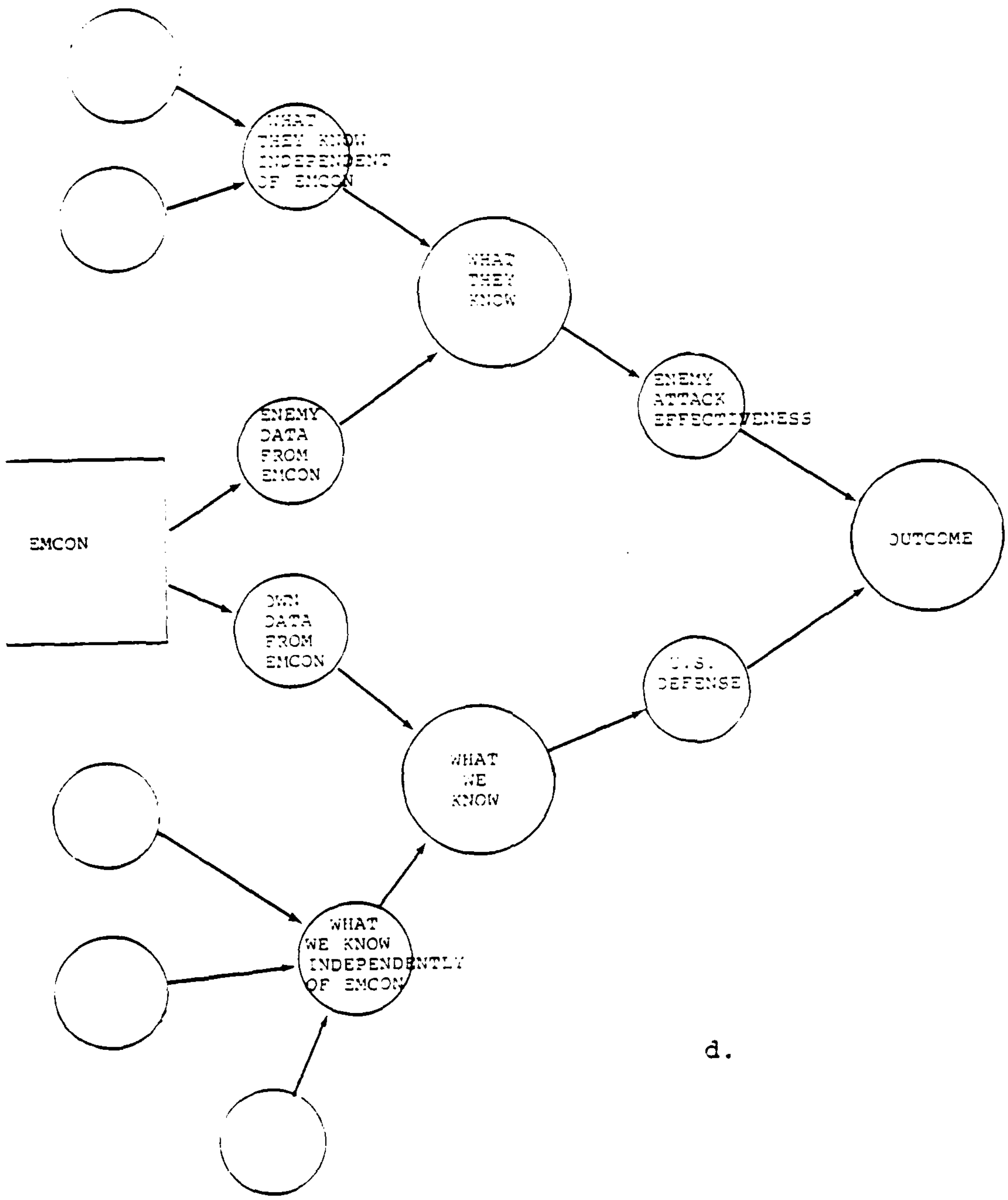


Figure A-7. Use of Influence Diagrams to Communicate to Final Interviewee (Cont'd)

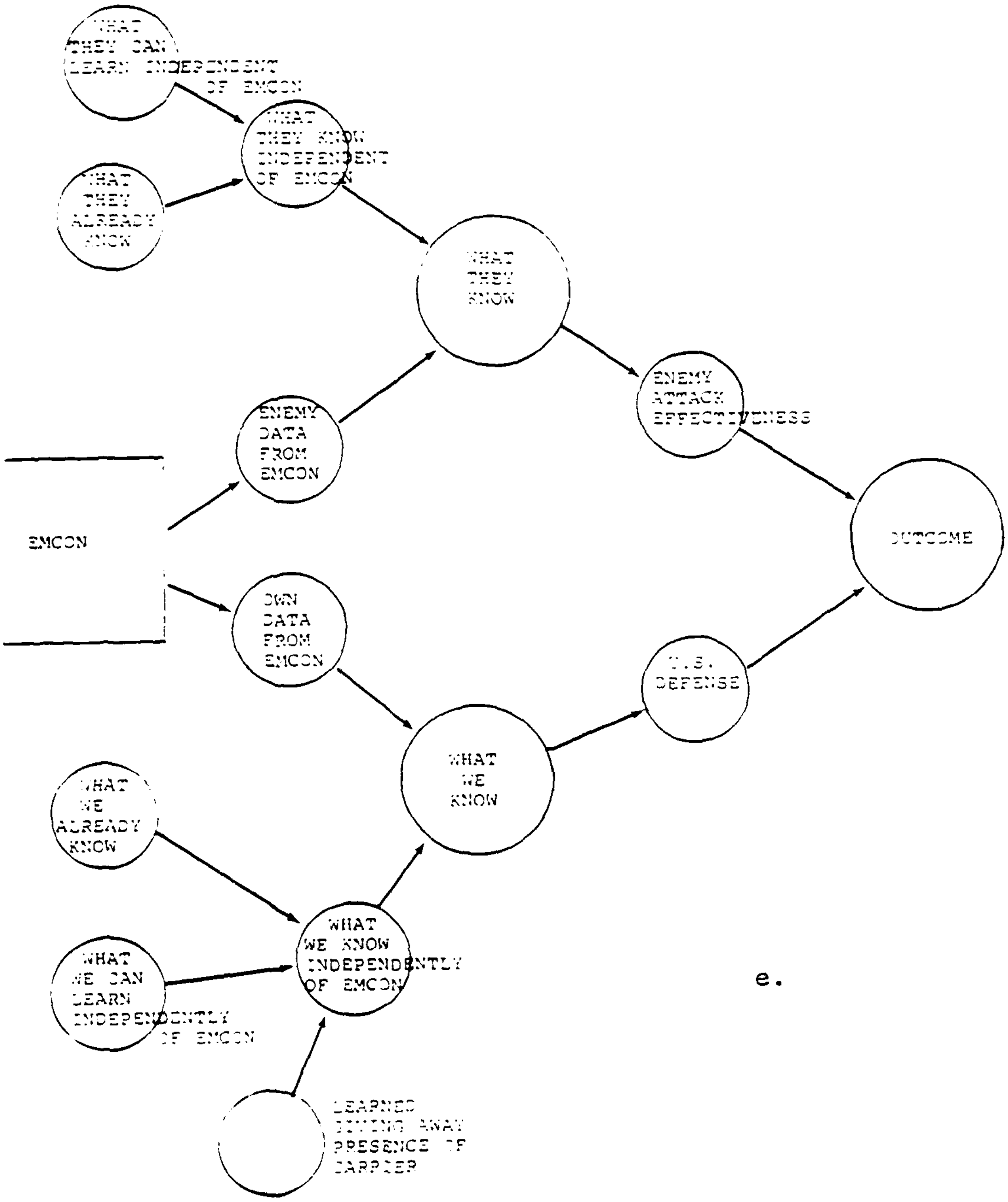


Figure A-7. Use of Influence Diagrams to Communicate to Final Interviewee (Cont'd)

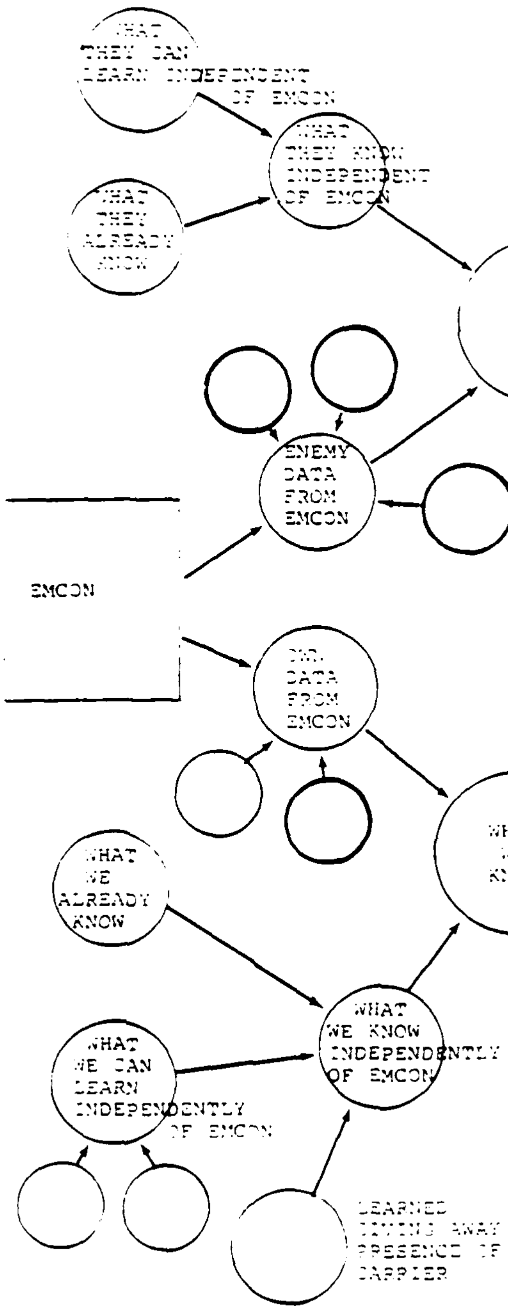


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Figure A-7. Use of Influence Diagrams to Communicate to Final Interviewee (Cont'd)

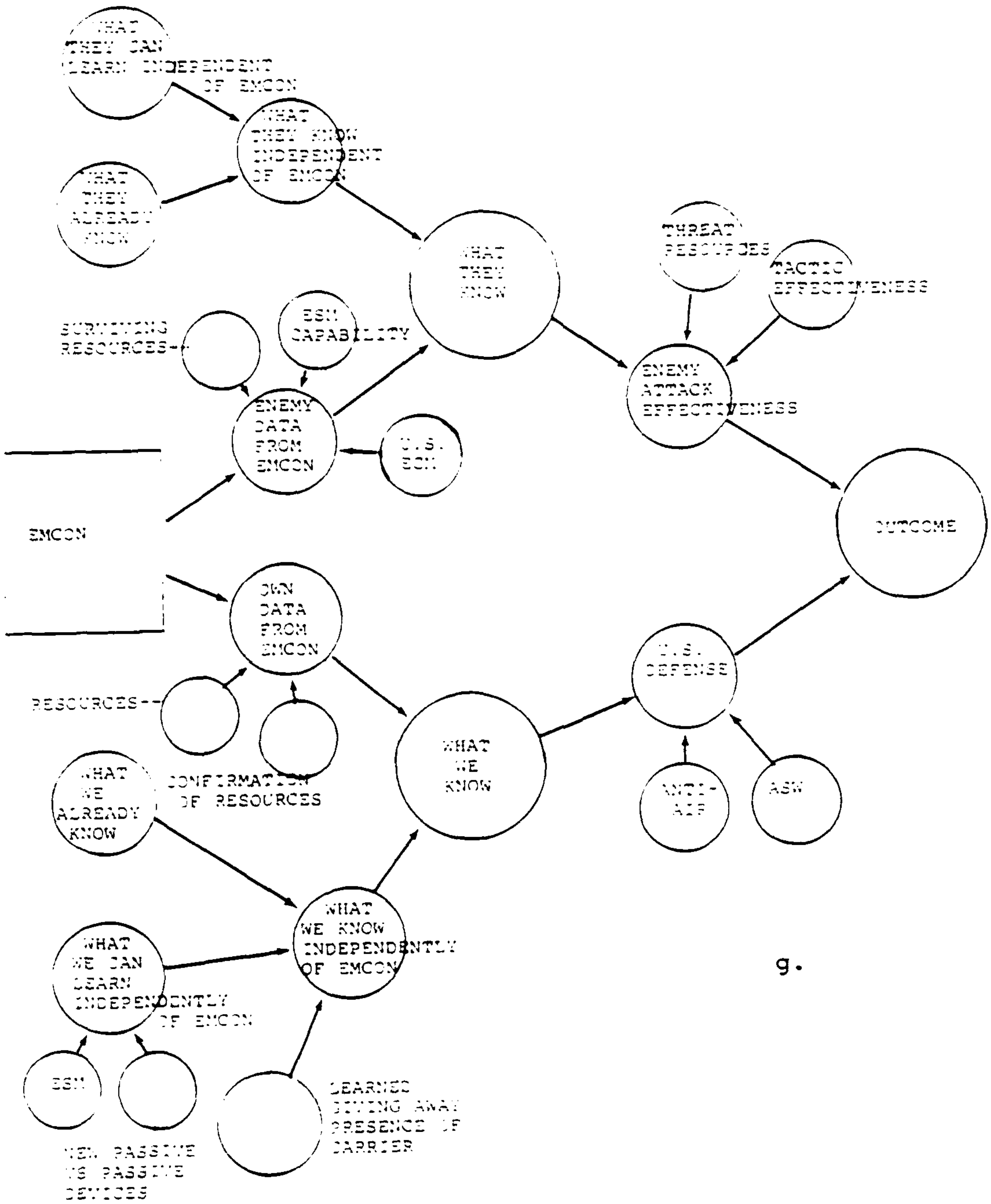


Figure A-7. Use of Influence Diagrams to Communicate to Final Interviewee (Cont'd)

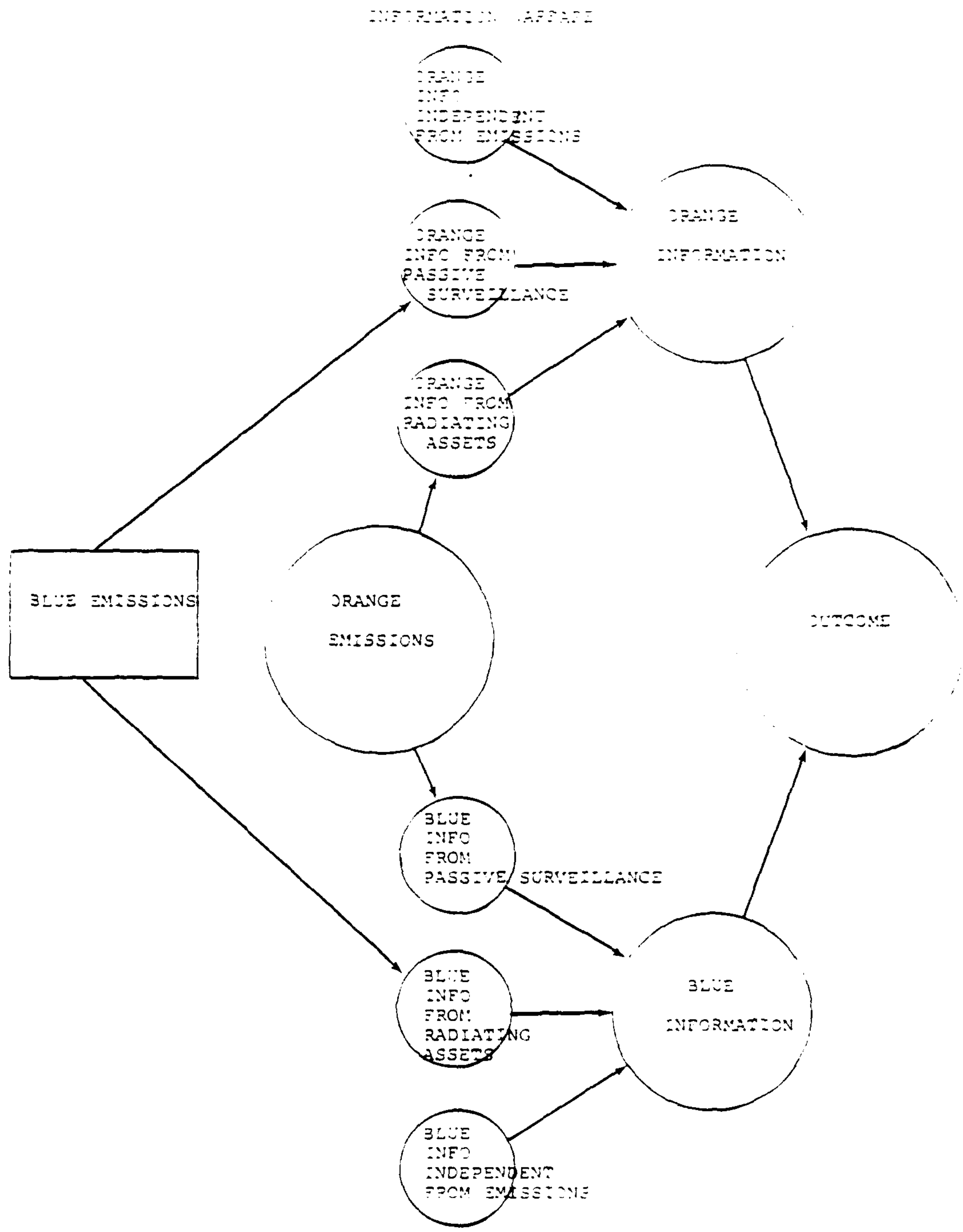


Figure A-8a. Overview of Revised Influence Diagram for Emissions Control in Information Warfare

ORANGE INFORMATION

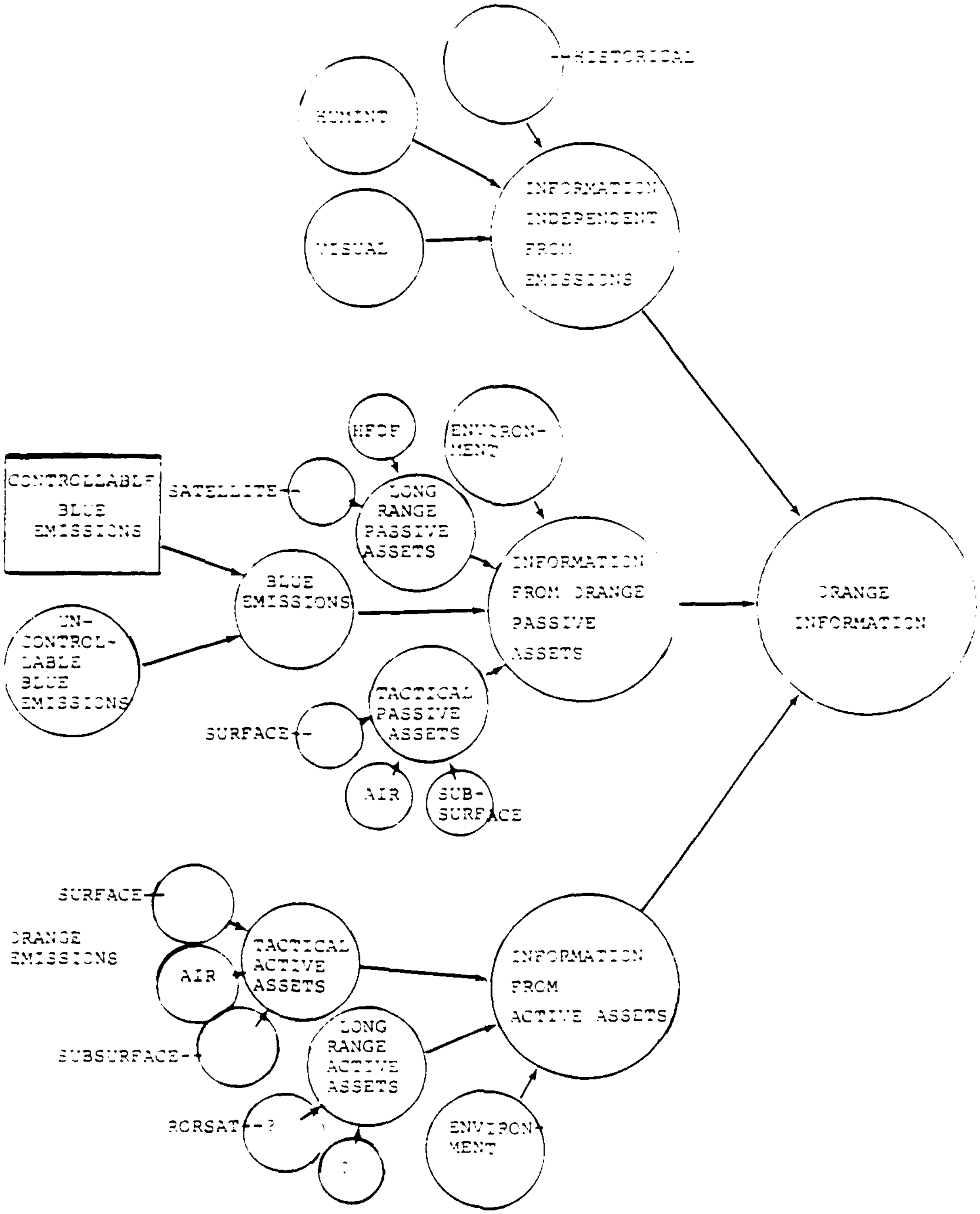


Figure A-8b. Detail of Orange Information From Revised Influence Diagram

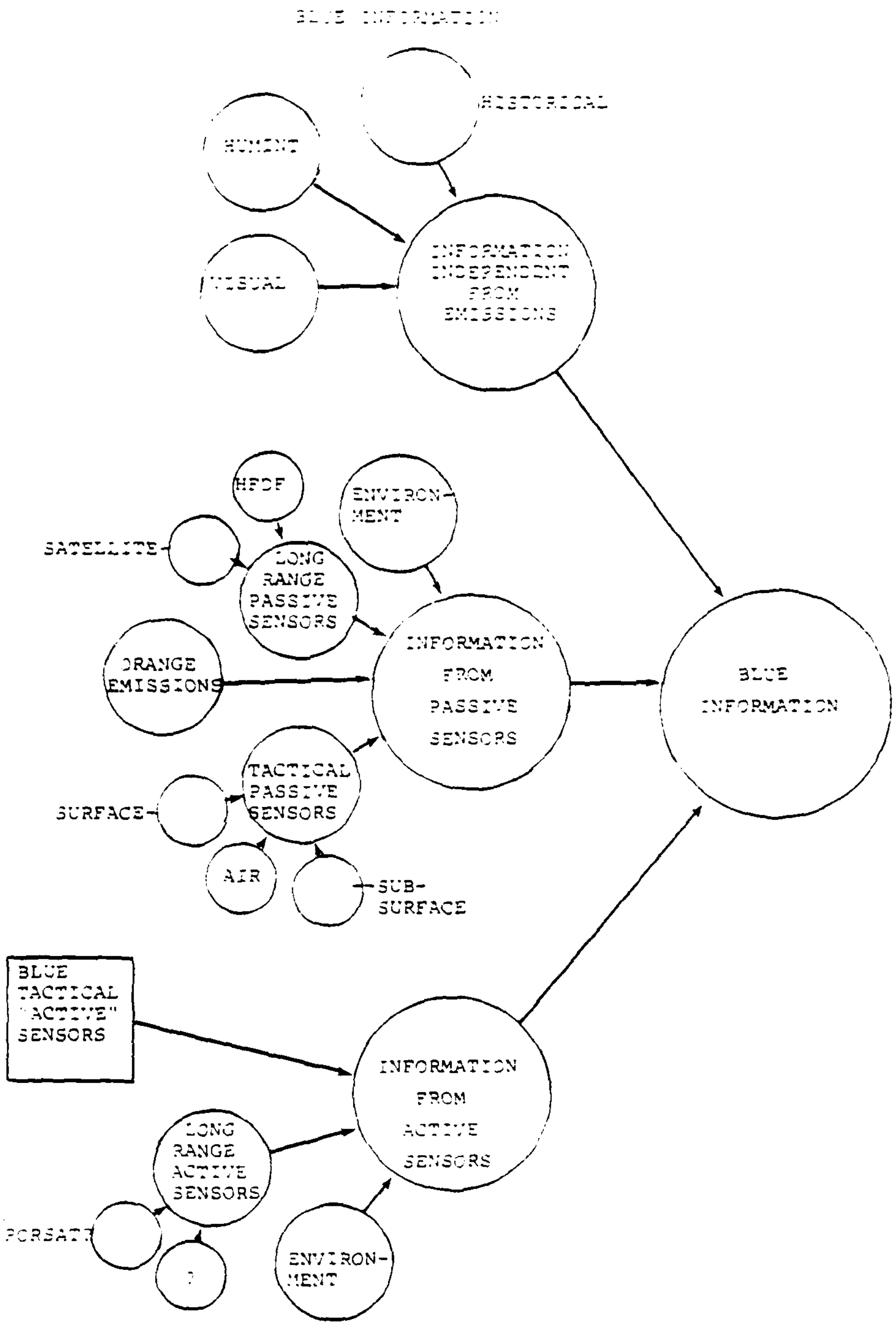


Figure A-8c. Detail of Blue Information From Revised Influence Diagram

EFFECTIVENESS OF TASK FORCE DEFENSE

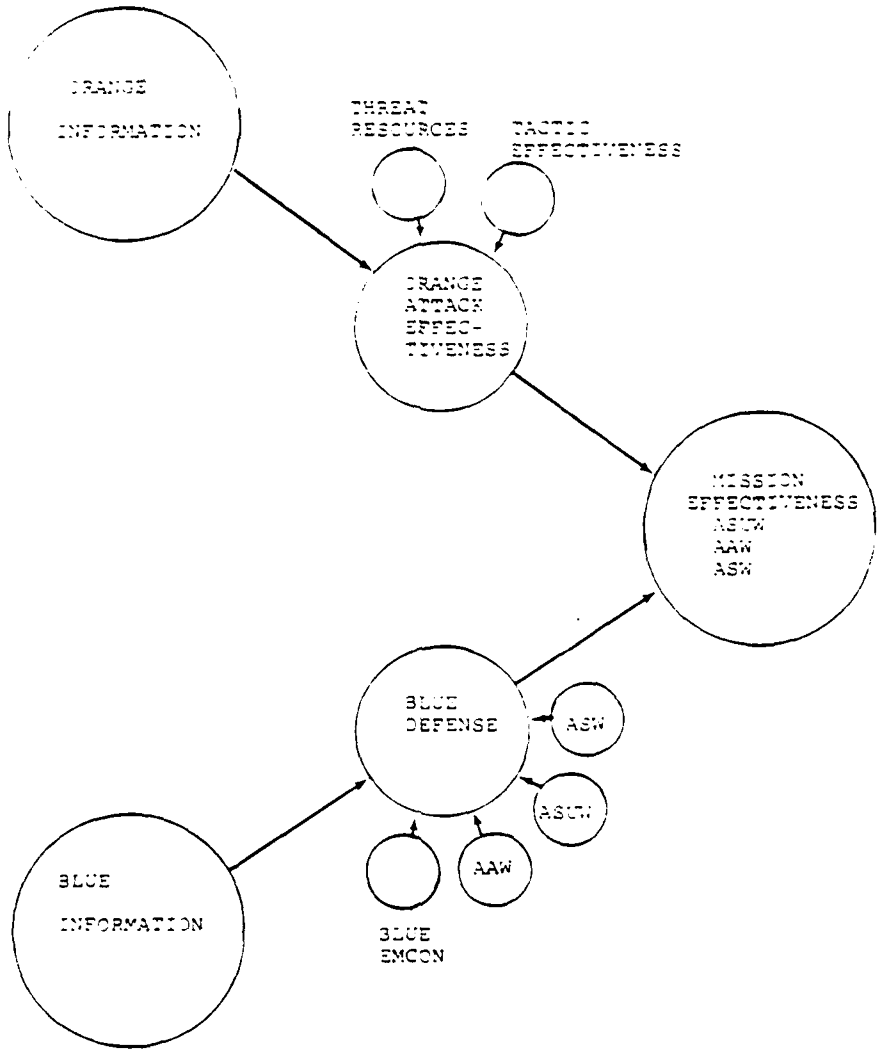


Figure A-8d. Detail of Outcome for Information State for a Particular Mission Objective: Task Group Defense Against Suprise Attack

The symmetry of Blue and Orange information warfare tactics implies a corresponding symmetry to the Blue and Orange information sources. Both sides receive information dependent on their own EMCON state but independent of adversary EMCON posture. Both sides receive information that depends on the adversary emissions but not on their own, and both sides receive some information that depends neither on their own emissions posture nor on their adversary's emissions posture.

Figures A-8b, c, and d display additional detail in the influence diagrams. The information independent of emissions includes historical knowledge of usual doctrine, information about probable mission objectives, knowledge about ship orders of battle, background information about which ships are likely to be in the task group, intelligence derived from human sources, and visual sightings.

The information obtained from Orange passive assets derives from Blue emissions, including both controlled emissions such as search radars, as well as those that are normally not controllable such as infrared radiations from ship hulls. Passive surveillance sensors are divided into two groups, tactical sensors within a few hundred miles of the task group, and long-range sensors possibly thousands of miles away. Reflecting Navy operations, tactical passive sensors are classified by their platforms. The diagram also indicates that the effectiveness of all passive systems depends on the environment.

The diagram detailing factors influencing Blue information is similar to the previous one summarizing sources of Orange information. Of course, the actual influences pertinent in any particular scenario would likely be significantly different for Orange and Blue, and the capabilities of the different information sources would be very different. Nevertheless, in these general diagrams, the different kinds of channels for receiving information are nearly the same for the two adversaries.

The final detailed influence diagram relates the Blue and Orange information states to one particular information warfare mission objective, task group defense from a possible surprise attack. Defense against a surprise attack is only one objective of emissions control and information warfare. It is not, of course, the only objective nor is it even the most likely one. Rather, it is included here to illustrate how the information possessed by Blue and Orange forces can be related to a larger objective. Similar influence diagrams could be constructed for other likely objectives of information warfare, such as diverting adversary forces from defense of a hostile target.

## A.5 MODIFICATION OF INFORMATION WARFARE INFLUENCE DIAGRAM FOR AID INTERFACE

The information warfare influence diagrams developed after the last interview were not sufficiently directed to EWAR applications to use directly in the aid interface. This interface required a design that conveyed overall aid architecture, that showed the relationships between influencing factors and aid outputs, and that could help the aid user calculate needed parameter values and perform desired sensitivity analyses. Therefore, the information obtained in these interviews was reformatted for the aid interface.

The following section describes the interface diagrams in detail. Those diagrams differ from the final information warfare diagram by de-emphasizing the fundamental symmetry in information warfare, by de-emphasizing factors of little concern to the emissions control applications, and by adding detail needed for aid calculations.

As an example of the symmetry decrease in the aid, the factor "Orange Emissions" in the general information warfare diagram is, for the aid interface, limited to include only emissions from possible hostile missiles or missile launch platforms. Blue emissions, on the other hand, include only tactical radars that can convey information about the task group disposition or which can help detect attacking Orange missiles. The Orange information from passive surveillance is limited to information pertinent to task group detection, localization, and classification. Orange information obtained from Blue attack missiles is not included in the aid interface because the aid is not concerned with Blue emissions control plans appropriate for an attack on Orange.

The aid interface de-emphasizes other information not central to the aid functions. In particular, the items "Historical," "Humint" (Human Intelligence), and "Visual" are not explicitly included in the aid interface. The information associated with these factors appears in the aid data base and in the factor "Current Orange Beliefs." On the other hand, the interface does include some factors important to the aid that are not explicitly *included in the* more general diagram. For example, the aid interface explicitly includes Orange beliefs about Blue doctrine, such as whether the Blue high value units are normally in the task group center or whether Blue normally selects emissions control postures that de-emphasize the high value units.

Finally, the aid interface differs from the general influence diagram by adding details needed for aid calculations. For example, the aid interface diagram includes factors for sensor sensitivities, missile radar cross sections, and radar antenna height. Such details would clutter a general diagram intended to show important relationships between variables. In the aid interface they inform the user both of what kind of data is needed for its calculations and also how that data affects the outcome displays.

## A.6 SUMMARY OF INTERVIEWS

The interviewing procedure adapted from the SRI decision aid and refined further by advice from OPNAV and NAVELEX officers seemed to work very well. It proved to be an efficient way for DSA to acquire the information required for the interface diagram. The influence diagrams, although lacking the detail that would be required in a classified survey of information warfare, contained enough detail for the desired user interface. The structure of the influence diagrams reflected the way Naval officers, involved with emissions control planning, structure this environment and facilitated an interface design with a structure that would seem natural to aid users. Perhaps most important, the interviews identified those areas in which the aid must be strengthened for its operational adoption and also indicated how the aid could interact with other shipboard systems.

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